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Introduction

Welcome to another course in the STEP series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to help our distributors and customers better understand Siemens Industry, Inc. products. This course covers **Basics of Electrical Products**.

Upon completion of **Basics of Electrical Products**, you should be able to:

- Explain how Siemens products are used in basic residential, commercial, and industrial applications
- Explain the similarities and differences between load centers, panelboards, switchboards, switchgear, and secondary unit substations
- Identify various Siemens products used in discrete parts manufacturing, assembly, batch processing, and continuous processing
- Identify various Siemens products by trade name

This knowledge will help you better understand product applications. In addition, you will be better prepared to discuss electrical products and systems with others. You should complete **Basics of Electricity** before attempting **Basics of Electrical Products**. Once you have completed **Basics of Electrical Products**, you should complete or review any of the other STEP courses that are relevant to your work. The general information provided in **Basics of Electrical Products** will help you better understand the specific product details in the remaining STEP courses.

After you have completed this course, if you wish to determine how well you have retained the information covered, you can complete a final exam online as described later in this course. If you pass the exam, you will be given the opportunity to print a certificate of completion from your computer.

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Siemens Industry, Inc.

Company Overview

The objective of this course is to provide a high-level overview of those products of **Siemens Industry, Inc. (SII)** which are sold by our channel partners and fall into the following categories: low voltage power distribution, motors, control, drives, and industrial automation. It is beyond the scope of this course to cover all SII products. For more information on SII products, refer to the Siemens Industry, Inc. web site.

Before discussing Siemens Industry, Inc. products, it is useful to briefly discuss our parent company, **Siemens AG**, and how SII fits into the Siemens worldwide business structure.

Siemens AG is a leading supplier of electrical and electronic equipment and associated services worldwide. From the initial Siemens company, founded in 1847, Siemens has grown become one of the largest companies with employees in 190 countries, including about 70,000 employees in the U.S.

Siemens AG offers a broad range of products and services in the following four business sectors: **Energy**, **Healthcare**, **Infrastructure & Cities**, and **Industry**.

Siemens AG is headquartered in Berlin and Munich and operates in most countries through regional cluster organizations. In the United States, Siemens has a number of operating companies, such as SII, that each focus on a portion of the total Siemens portfolio of products and services.

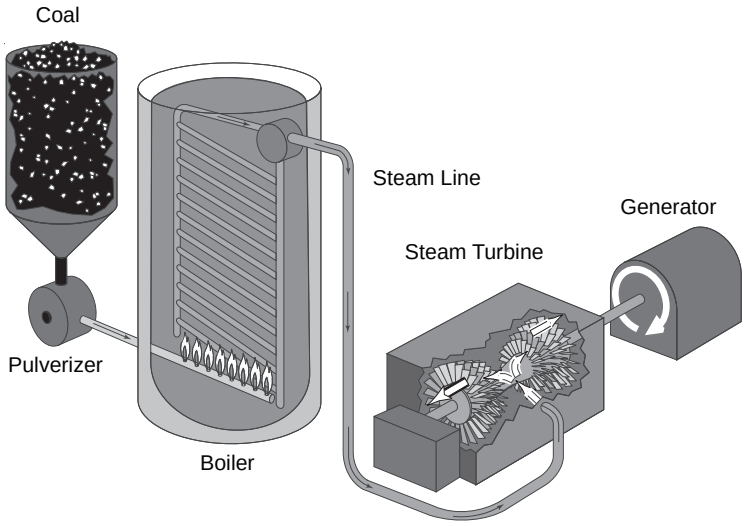
In order to help you better understand SII's low voltage power distribution products, motors, control, drives, and industrial automation, this course looks at where many of these products fit in the flow of energy in sample residential, commercial, and industrial applications. Keep in mind that the flow of energy from the electric utility is discussed only briefly in this course because utility power generation, transmission, and high-voltage distribution products and services are the responsibility of Siemens Energy sector companies.

Electric Power

Power, originating at a power generating plant, is distributed to residential, commercial, and industrial customers through various transmission lines and substations.

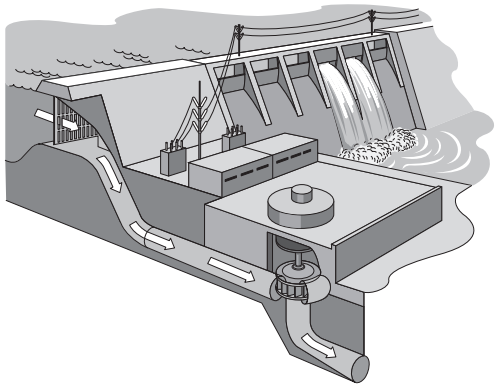
Power Sources

There are several energy sources used to produce electrical power. For example, coal, oil, and uranium are fuels used to convert water into steam which, in turn, drives a turbine. Some utilities also use gas turbines, or, for combined cycle operation, both gas and steam turbines. The output shaft of the turbine is connected to an **alternating current (AC) generator**. The AC generator is rotated by the turbine. It is the AC generator which converts the mechanical energy into electrical energy.



Hydroelectric Power

Hydroelectric power plants use mechanical energy from falling water to turn a generator.



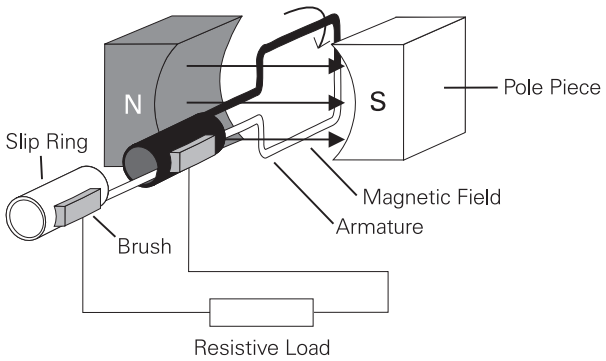
Newer Renewable Energy Sources

Of the power generation approaches discussed so far, only hydroelectric power is a renewable energy source. Hydroelectric power has been around from the earliest days of electric power generation. In recent years, a small, but growing, percentage of electrical energy is generated using wind or solar power or through a host of other renewable approaches.

AC Generators

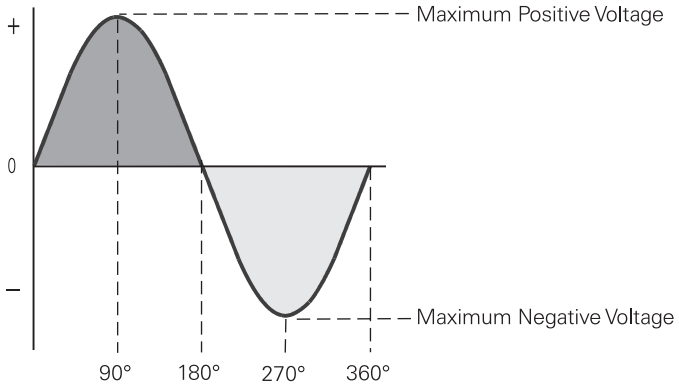
Most of the technologies in use today to generate electricity utilize an AC generator. AC generators operate on the theory of electromagnetic induction. This simply means that, when conductors are moved through a magnetic field, a voltage is induced into the conductors.

Although commercial power generators are complex machines, for the purpose of explanation, a basic generator can be constructed of magnets, an armature, slip rings, brushes, and some type of resistive load. An armature is any number of conductors wound in loops which rotate through the magnetic field created by the magnets. For simplicity, one loop is shown below.



If you track the rotation of the AC generator through a complete revolution of 360°, you would see that, during the first quarter of a revolution, voltage increases until it reaches a maximum positive value at 90°. Voltage decreases during the second quarter of a revolution until it reaches zero at 180°. During the third quarter of a revolution, voltage increases in the opposite direction until it reaches a maximum negative value at 270°. During the last quarter of a revolution, voltage decreases until it reaches zero at 360°.

This is one complete cycle of operation. If the armature of this simple AC generator rotates 3600 times per minute (3600 RPM), it produces 60 cycles of voltage per second, or 60 hertz.



Energy Transfer

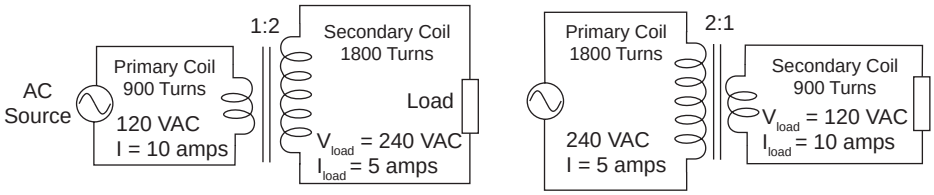
The role of the generator just described is to change mechanical energy into electrical energy. In order for this energy to be useful, however, it must be transmitted to the utility's customers via transmission lines. The most efficient way to do this is to increase the voltage while at the same time reducing the current. This is necessary to minimize the energy lost in heat on the transmission lines. These losses are referred to as **I^2R (I-squared-R)** losses because they are equal to the square of the current times the resistance of the power lines.

Transformers

Once the electrical energy gets near the end user, the utility steps down the voltage to the level needed by the user. The device that utilities use to step up the voltage at the generator end and step down the voltage at the user end is called a **transformer**.

The transformer transfers energy from a primary coil to a secondary coil by mutual induction. The AC generator provides electrical power to the primary coil. The magnetic field produced by the primary coil induces a voltage into the secondary coil, which supplies power to the connected load. The load in this case is the entire electrical distribution network including all residential, commercial, and industrial customers.

A **step-up transformer** is used when it is desirable to step voltage up from one level to another. The following simplified example shows a 1:2 step-up transformer could be used to step 120 volts up to 240 volts. A 2:1 **step-down transformer** could be used to step 240 volts down to 120 volts. Keep in mind that most transformers step up or down the voltage more significantly than this simple example displays.

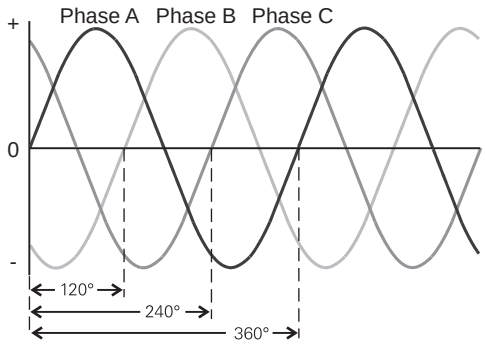


Step-Up Transformer

Step-Down Transformer

Three-Phase Voltage

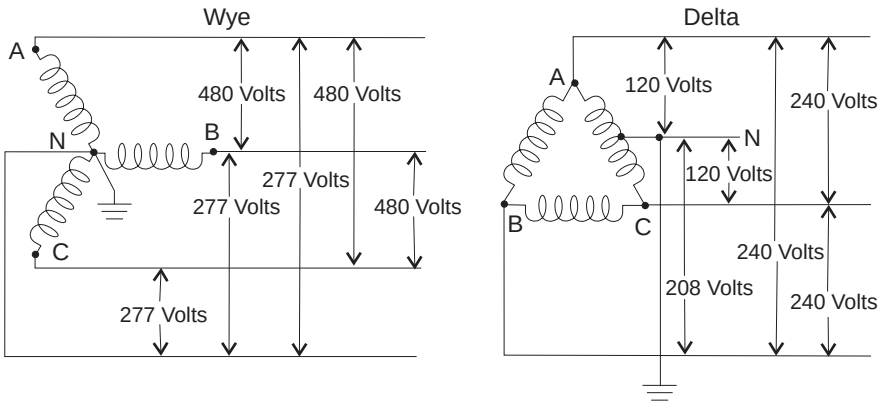
For simplicity, the generator and transformers shown so far have been **single-phase** devices. While single-phase power is needed for many applications, utilities generate and transmit **three-phase** power. In a three-phase system, the generator produces three voltages. Each voltage phase rises and falls at the same frequency (60 Hz in the U.S., 50 Hz in many other countries); however, the phases are offset from each other by 120°.



Three-Phase Transformers

Transformers used with three-phase power require three interconnected coils in both the primary and the secondary. These transformers can be connected in either a **wye** or a **delta** configuration. The type of transformer and the actual voltage depend on the requirements of the power company and the needs of the customer.

The following illustration shows the secondary of a wye-connected transformer and the secondary of a delta-connected transformer. These are only examples of possible distribution configurations, the specific voltages and configurations vary widely depending upon the application requirements.



A - B	480 Volts
B - C	480 Volts
C - A	480 Volts
A - N	277 Volts
B - N	277 Volts
C - N	277 Volts

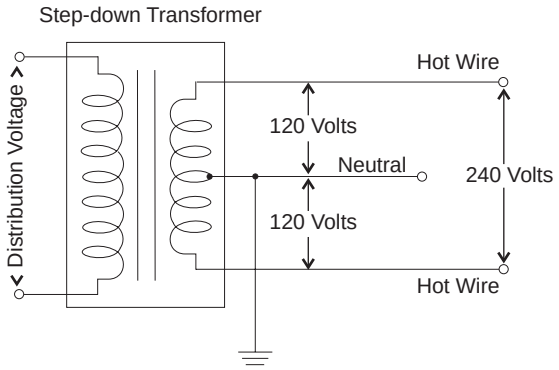
A - B	240 Volts
B - C	240 Volts
C - A	240 Volts
A - N	120 Volts
B - N	208 Volts
C - N	120 Volts

Residential Applications

Power, generated at a power plant and stepped up to a high transmission voltage, is brought to a local substation. Here, it is stepped down to a lower distribution voltage. When it reaches its final destination at a residential customer, it is stepped down to 240 volts. Only single-phase power is used in a typical residential application.

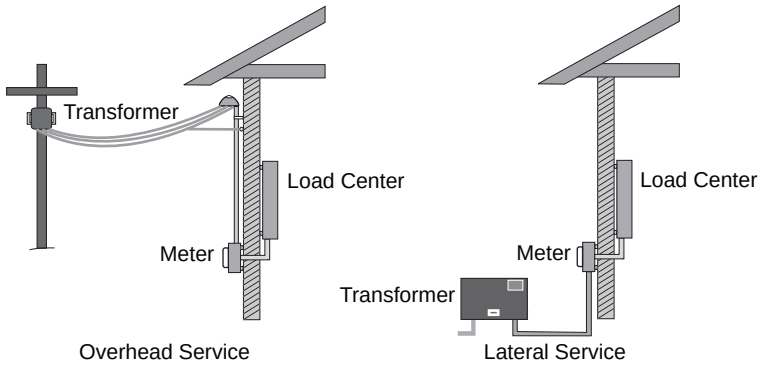
Power Supply

The most common supply system used in U.S. residential applications today is a **single-phase, three-wire supply system**. In this system, the voltage between either hot wire and neutral is 120 volts and the voltage between the two hot wires is 240 volts. The 120 volt supply is used for general-purpose receptacles and lighting. The 240 volt supply is used for heating, cooling, cooking, and other high-demand loads.



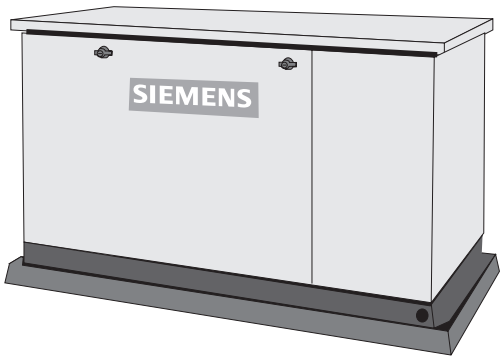
Service Entrance

Power, purchased from a utility company, enters the house through a metering device and is applied to a load center. This is the **service entrance**. Residential service can come from an overhead utility transformer or from a lateral service run underground.



Siemens Generators

Although the power from electric companies is usually reliable enough for residential applications, many homeowners and businesses desire **standby** or **portable generators**. Siemens generators are designed for quiet and reliable operation. Siemens offers generators in a range of capacities along with associated equipment, such as transfer switches and manual transfer interlock kits.



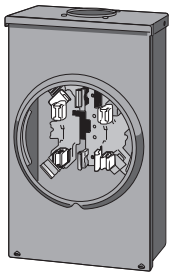
Microinverters

Solar panels are another source of power for homes and commercial facilities. However, these panels convert sunlight into direct current (DC), and the electrical equipment we use typically requires AC. Therefore, inverters are needed to make the conversion. For residential applications, the amount of energy converted is small and **microinverters** are used. Siemens microinverters and related equipment are safe and reliable. The trunk and drop cable system reduces installation time. Once in operation, a web-based monitoring system provides a module by module analysis.

Siemens Microinverter

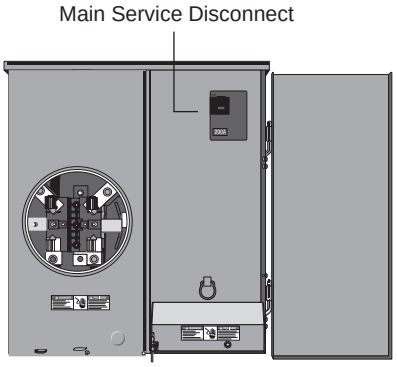
Meter Sockets

Most of us are familiar with the **watt-hour meter** located outside our homes. The watt-hour meter is typically provided by the power company and is used to determine how much electricity has been consumed for billing purposes. Each watt-hour meter requires a meter socket to safely and securely connect it to the electrical service. Siemens manufactures a variety of single-position and multiple-position **meter sockets**.

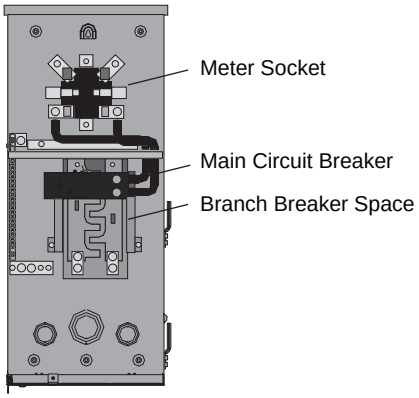


Meter Mains and Meter Load Center Combinations

Meter mains and **meter load center combinations** are similar. Meter mains incorporate space for a watt-hour meter and a main service disconnect within the same enclosure. Meter load center combinations incorporate space for a watt-hour meter and circuit breakers in the same enclosure. Because application requirements vary significantly, Siemens offers various types of meter mains and meter load center combinations.



Meter Main

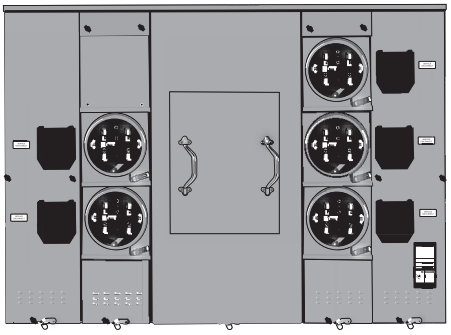


Meter Load Center Combination

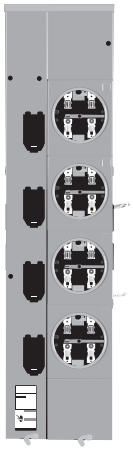
Group Metering

Uni-Pak meter centers are an option for multi-family dwellings. These are self-contained systems with two to six meter compartments. Individual branch circuit breakers for each tenant are located in a separate compartment adjacent to each meter socket.

Power Mod with QuickSystem modular metering includes an assortment of module types that can be easily configured to meet a wide range of residential and commercial group metering applications. For example, a typical application requires a main device module and one or more residential or commercial meter stacks.



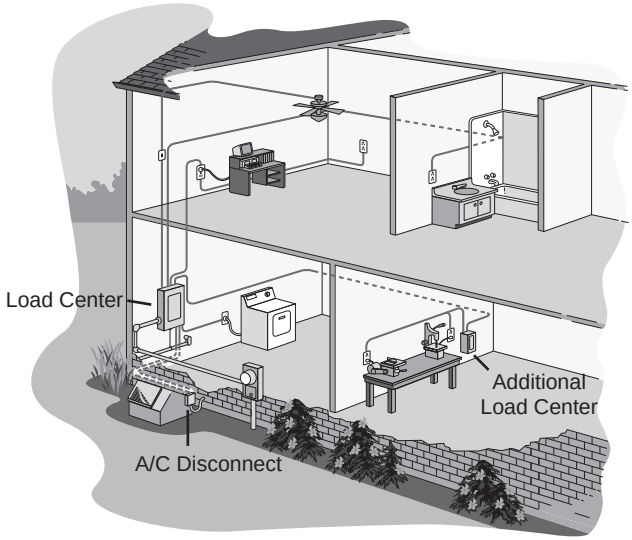
Uni-Pak Meter Center



Power Mod Meter Stack

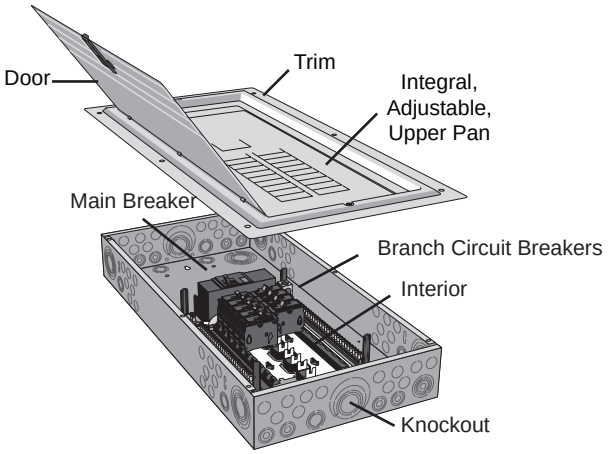
Residential Power Distribution

After passing through a meter, incoming power usually goes to a **load center**. Load center is an industry term used to identify a type of **panelboard** used in residential or light commercial applications. As previously indicated, this load center may be combined in the same enclosure with a meter socket. Often, however, a separate load center is provided. In some instances, typically where there has been subsequent construction, a second load center is used for additional circuits. Where a central air conditioning unit is used, an electrical service disconnect device is often provided to remove power from the unit while maintenance is performed.



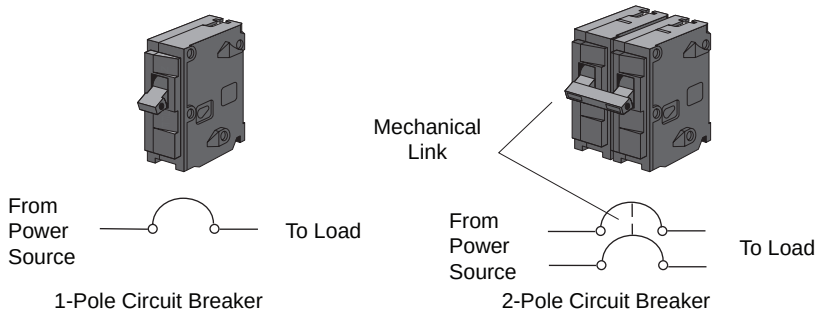
Load Centers

A typical load center consists of an enclosure, interior, and trim. A load center may have a main circuit breaker, but, if a main circuit breaker is provided separately, a main lug only type load center can be used. Branch circuit breakers plug into the interior to provide circuit protection and control for branch circuits. Load centers vary in size and ratings. For example, Siemens **PL** and **ES load centers** are available with continuous current ratings from 100 to 225 amps.

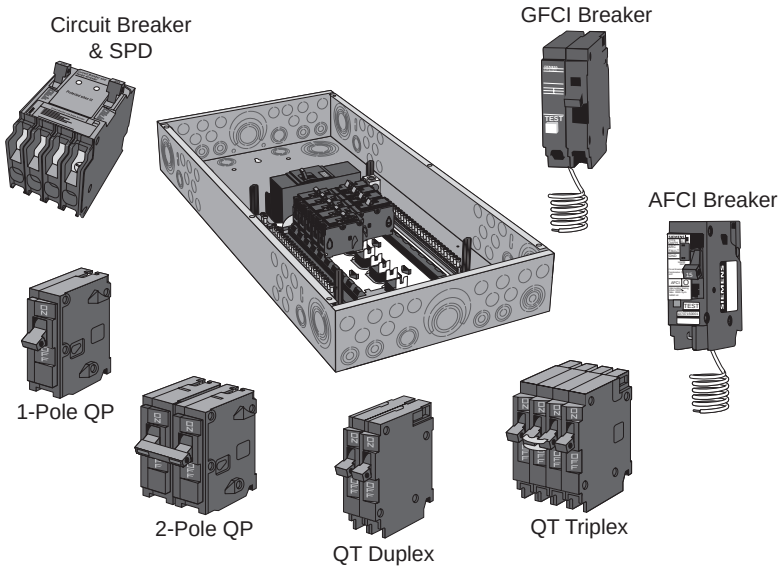


Circuit Breakers

Circuit breakers provide a manual means of energizing and de-energizing a circuit and overcurrent protection for the connected circuits. Residential circuit breakers are typically 1-pole, 2-pole, or 4-pole breakers with current ratings of 225 amps or less and voltage ratings of 120 volts, 120/240 volts, or 240 volts.



In addition to standard width **QP circuit breakers**, Siemens manufactures a variety of other branch circuit breaker types.



GFCI Circuit Breaker

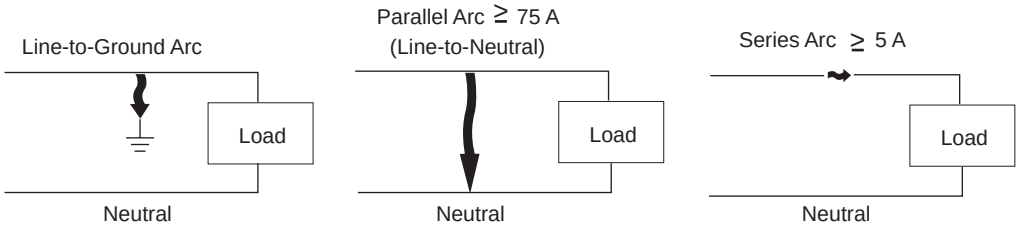
A **ground fault circuit interrupter (GFCI)** is required on certain residential receptacles, such as bathroom receptacles, receptacles located within six feet of a kitchen sink, and outdoor receptacles. A **ground fault** is a condition where current takes an undesirable path to ground. GFCI devices are designed to interrupt a circuit when a ground fault occurs. This is necessary to reduce the shock hazard. Often a GFCI is mounted at the receptacle. When this is not practical, a Siemens **GFCI circuit breaker** can be installed in the load center to provide this protection.

AFCI Circuit Breaker

Arc faults are electrical arcs which result when current flows in unintended ways, but, in residential applications, often not in sufficient amounts to cause a standard circuit breaker to trip. Arc faults in residential applications typically result from worn or damaged insulation and are a common cause of fires.

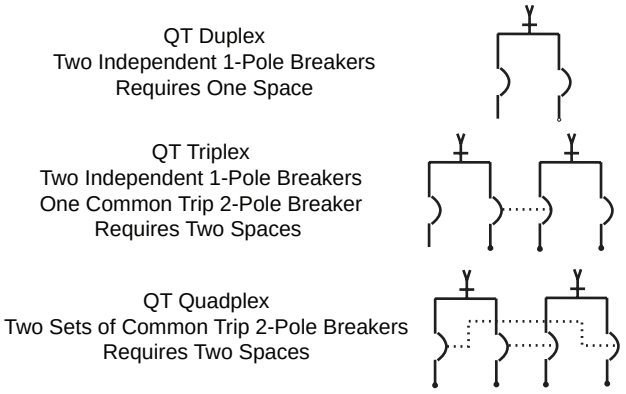
An **arc fault circuit interrupter (AFCI) circuit breaker** protects against a fire being started by arc faults by recognizing the characteristics unique to arcing and de-energizing the circuit when an arc fault is detected. Not all AFCI circuit breakers are the same, however.

Combination type AFCI (CAFCI) circuit breakers, in addition to providing overcurrent protection, are intended to protect downstream wiring from three categories of arc faults: line-to-ground arcs, high energy parallel arcs, and series arcs greater than or equal to 5 A. Series arcs are arcs on a single conductor.



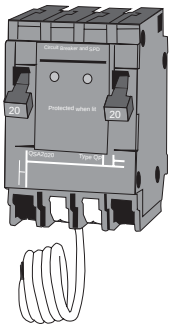
QT Circuit Breakers

Some Siemens load centers are designed to accept **type QT Duplex, Triplex,** and **Quadplex plug-in circuit breakers**. These are space saving breakers that are half the width per pole of type QP circuit breakers. This reduced width allows more circuits to be serviced from a load center, provided that the main circuit breaker has sufficient capacity. An important use for QT breakers is in cases where additional circuits are being added to an existing load center, but not enough spaces are available in the load center.



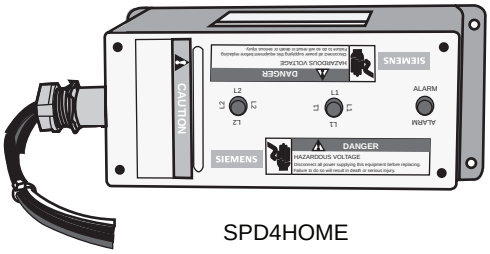
Point of Entry Surge Protection

Siemens residential products include devices intended to minimize damage from electrical surges. For example, Siemens **Circuit Breaker and SPD** replaces two full-size, 1-pole circuit breakers and provides surge protection for all branch circuits.



Circuit Breaker and SPD

Siemens also offers the following **surge protection devices (SPDs)** for use in residential and light commercial applications. Siemens **SPD4HOME** provides point-of-entry surge protection and can be used with either Siemens or competitor load centers. Siemens **SPD4TEL** telecommunication protector and **SPD4COAX** coaxial protector are UL listed devices that provide lightning protection for equipment connected to telephone lines (SPD4TEL) or TV cables (SPD4COAX).



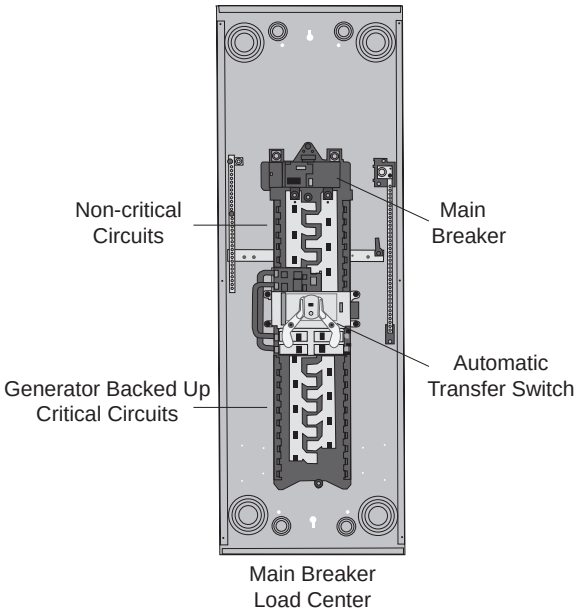
SPD4HOME

SPD4TEL

SPD4COAX

Special Application Panels

Siemens **Generator Ready Load Center** is a UL listed 200 A, 30 circuit, 42 space indoor load center that provides an effective solution for implementing generator backup of critical circuits. Both main lug only and main breaker versions are available.



Renovation panels are designed for renovation projects in older homes in which the distance between studs is narrower than current construction practices provide. Use of this narrower panel eliminates the need to notch out existing studs.

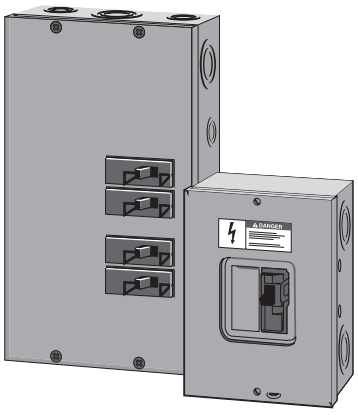
Riser panels are intended for use in high-rise applications. The interior in riser load centers is shifted to the left to allow extra room for riser cables to pass through. Siemens main lug riser panels are available with 125 or 200 amp ratings. Main breaker conversion kits are available. The panels may be mounted with main lugs on top or inverted to allow cables to pass on the opposite side.

Spa panels are designed for outdoor applications requiring the use of a ground fault circuit interrupter (GFCI). These panels incorporate a 2-pole GFCI breaker and provide two extra circuits.

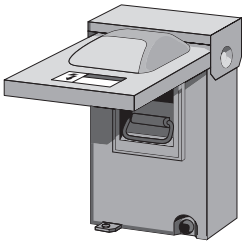
Temporary power outlet panels provide a variety of options for UL listed power outlets suitable for use as temporary service equipment during construction or as recreational vehicle power supply panels.

Enclosed Circuit Breakers and Disconnects

Siemens manufactures circuit breaker enclosures and fused, non-fused, and molded case switch disconnects. **Enclosed circuit breakers** and **disconnects** provide a convenient means of disconnecting power to allow for the maintenance of equipment, such as an air conditioner.



Enclosed Circuit Breakers



Enclosed Disconnect

Electric Vehicle Charging Solutions

VersiCharge is a family of level 2 AC charging stations that includes 30 amp and 70 amp VersiCharge and VersiCharge SG models. **VersiCharge** and **VersiCharge SG** models have easy-to-use controls and are designed to be easy and safe to install. VersiCharge SG models have additional communication and metering functionality.

	VersiCharge and VersiCharge SG Models	
	30 A Models	70 A Models
Input Voltage	240 VAC or 208 VAC	
Minimum Branch Circuit Rating	40 A	90 A
Output Power	Up to 7.2 kW	Up to 16.8 kW

Review 1

1. _____ incorporate space for a watt-hour meter and a main service disconnect in the same enclosure.

2. _____ and _____ provide enclosure options for the multiple watt-hour meters required in multiple family dwellings.

3. Siemens PL and ES load centers have continuous current ratings from ___ to ___ amps.

4. Siemens _____ AFCI circuit breakers provide protection against all three known types of arc faults.

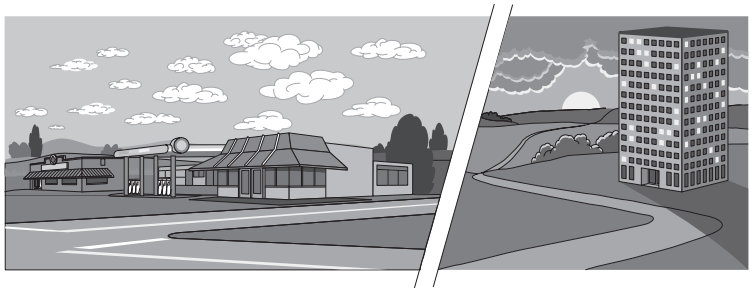
5. Siemens Circuit Breaker and _____ provides point of entry surge protection and also incorporates two 1-pole breakers.

Commercial Applications

Commercial applications range from small offices and stores to larger complexes such as hotels, office buildings, and shopping malls. These applications differ in the amount of electrical energy required. Small, single-tenant office buildings, for example, have very limited power requirements. In such cases, a single-position meter socket and panelboard may be sufficient for distributing power.

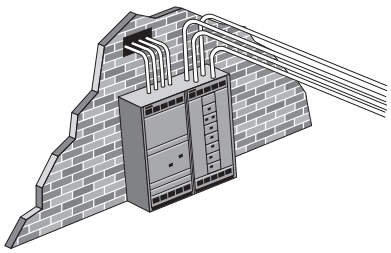
Multiple-tenant applications, such a small strip mall or apartment building, usually require multiple utility meters. In these cases, metering systems or modular meter centers, as described previously, are often used.

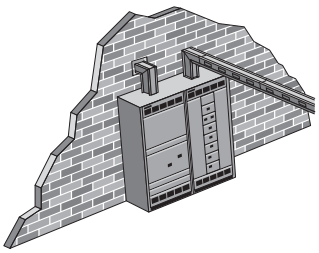
Typically, however, commercial applications have higher demands for electrical power than single-family residential applications. Electricity is used in commercial applications for heating, cooling, and lighting on a much larger scale. In addition, many commercial applications also operate machinery such as elevators, escalators, and conveyors.



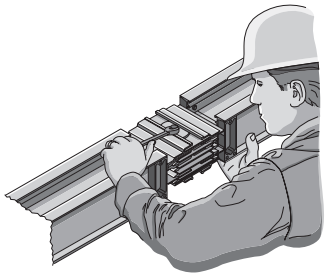
Busway

There are two methods to route power into a building and distribute power throughout the building. Electrical cable can be run inside conduit or a **busway** system can be used. Most small and medium-sized commercial facilities typically use only cable and conduit to route power. In large facilities, such as a multi-story office building, the power distribution system often incorporates a combination of busway and cable and conduit.



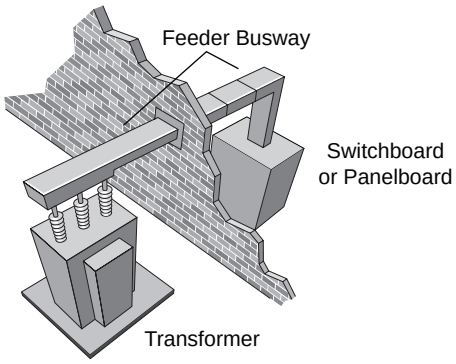


Busway is a system of enclosed and insulated conductors and associated fittings and accessories manufactured for rapid assembly at the job site. Siemens offers a variety of busway systems including **Sentron busway**. Sentron busway has an easy to install design and is available with continuous current ratings from 225 to 5000 amps.



Service Entrance

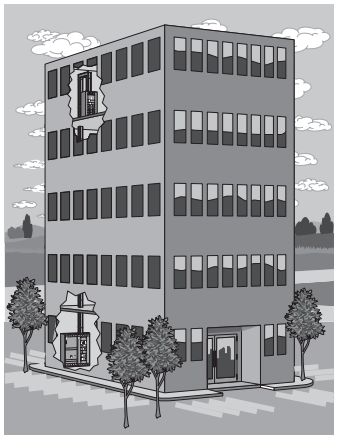
Outdoor feeder busway is often used as service entrance conductors to bring power to a switchboard or panelboard. This may involve routing power from outside the building or from a transformer vault inside the building. For distribution inside the building, indoor feeder or plug-in busway can be used.



The Busway Advantage

A major advantage of busway is the ease in which busway sections are connected together. Electrical power can be supplied to any area of a building by connecting standard lengths of busway. It typically takes less labor to install or change a busway system than cable and conduit assemblies. Savings of 25 to 30% of the total installation cost are common when busway is used.

Busway risers (vertical busway) can be installed economically in a high-rise building, such as the one illustrated below, where it can be used to distribute power to lighting and air-conditioning loads.



Power Distribution in Commercial Applications

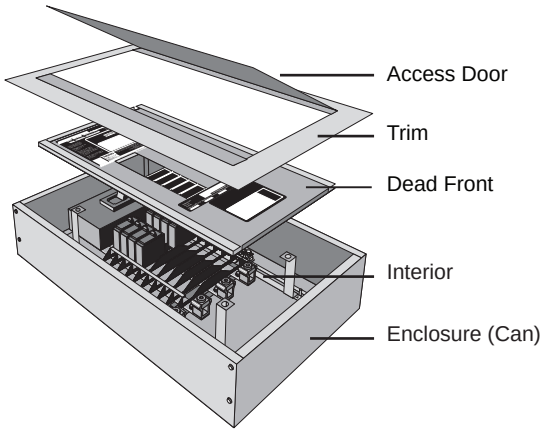
The power control and circuit protection needs of a small commercial facility can often be met with a single lighting and appliance panelboard. For larger applications, however, the incoming service typically connects to a **switchboard** or **power panelboard**. Additional switchboard sections or power panelboards may be required to control feeder circuits which provide power to downstream panels.

While panelboards and switchboards both perform power control and circuit protection functions, there are key differences between these systems. For example, a panelboard must be mounted in or against a wall; whereas, some switchboards must be installed away from a wall to allow access to the rear of the unit for installation and maintenance purposes.

Perhaps the key difference, however, is the amount of power controlled by each type of system. In general, switchboards can be configured to include larger circuit breakers or switches so that they can handle greater amounts of current. This also means that switchboards may be more complex and can incorporate a broader range of devices.

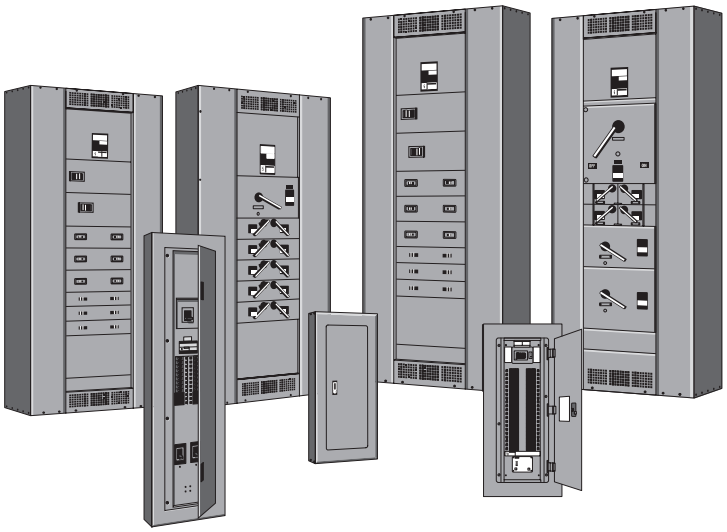
Panelboard Construction

The load centers discussed previously in this course are panelboards designed for residential or light commercial applications. Panelboards used in most commercial applications, however, are generally more rugged in construction and able to handle larger amounts of current.



Panelboards

Siemens manufactures a range of panelboard models to meet various distribution requirements.



The **P1** panel fits the majority of lighting and appliance panel needs in a cost effective package. P1 main breaker or main lug only panels are available with continuous current ratings up to 400 amps.

The next step in the series is the **P2** panel which offers maximum flexibility and options to fit demanding specifications. P2 main breaker or main lug only panels are available with continous current ratings up to 600 amps.

The **P3** panel is also a flexible and innovative panel. P3 panels are sized more like a lighting and appliance panel for those tight areas, but able to handle many power distribution panel applications. P3 panels are available with continuous current ratings up to 800 amps for main lug only panels and 600 amps for main breaker panels.

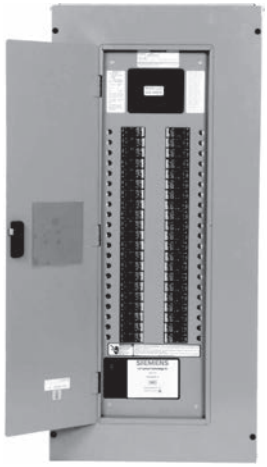
The **P4** panel is a mid-sized power distribution panel that can include fusible switches as well as circuit breaker main and branch devices. P4 panels are available with continuous current ratings up to 1200 amps for main lug only panels, 800 amps for main breaker panels, and 200 amps for main switch panels.

The **P5** panel incorporates larger fusible and circuit breaker main and branch devices to provide maximum power to the distribution system. P5 panels are available with continuous current ratings up to 1200 amps for main lug only, main breaker, and main switch panels.

Finally, the **Coordination Panelboard** makes it simple and cost effective to selectively coordinate a fused electrical distribution system compatible with *NEC*® requirements. These panelboards are available with continuous current ratings up to 400 amps.

Lighting Control Panels

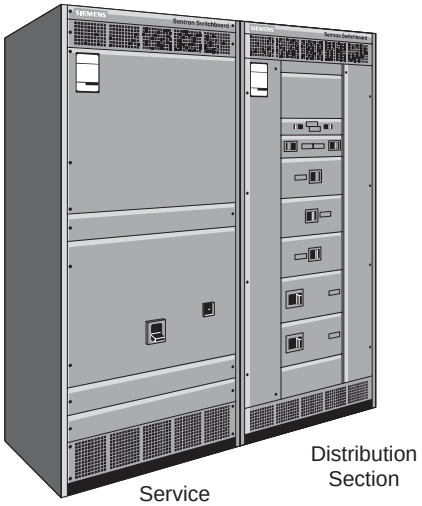
The **P1 Series Lighting Panelboard with i-3 V2 Control Technology** is designed to provide a simple, flexible, compact solution for controlling branch lighting circuits remotely via a time schedule or an external signal. Our i-3 V2 Control Technology incorporates programmable remote control of **SIPODs**, which are automated contactors connected to the load side of **BQD** frame breakers. This modular design produces a smart breaker system that lowers installation costs and simplifies future system modifications.



Siemens P1 Series Lighting Panel with i-3 V2 Control Technology

Switchboard Construction

Switchboards typically consist of a service section with a main circuit breaker or main fusible switch and one or more distribution sections. The service section can be fed directly from the utility transformer. In addition to the main disconnect, the service section usually contains utility or customer metering provisions.



SB1, SB2, SB3, and RCS Switchboards

SB1, SB2, and SB3 switchboards have been designed to simplify system layout and reduce installation cost. They are built to **Underwriter's Laboratory** (UL 891) and **National Electrical Manufacturers Association** (NEMA PB-2) standards and provide rugged construction and service flexibility.

SB1 switchboards are designed fit in limited floor space. Through-bus ratings up to 2000 amps at 600 VAC are available. The main protective devices are front-connected. All sections are rear aligned so that the switchboard can be installed against a wall.

SB2 main protective devices and through-bus are rated up to 4000 amps at 600 VAC. The rear of all sections align as standard. Front and rear alignment is available as an option.

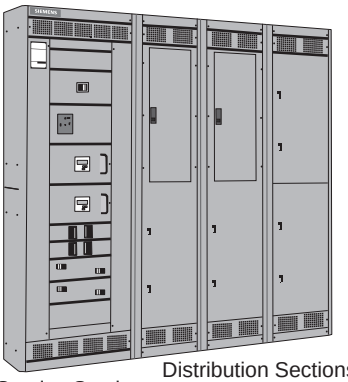
SB3 switchboards offer the greatest variety of options and are available with a main bus rating up to 6000 amps at 600 VAC. The rear of all sections align as standard. Front and rear alignment is available as an option.

RCS (rear-connected) switchboards differ from the SB1, SB2, and SB3 design primarily in the distribution section, which uses individually mounted branch feeders. Because of the mounting method, access to the outgoing cable terminals must be from the rear of the RCS section. RCS switchboards are available with a main bus rating up to 6000 amps at 600 VAC.

Integrated Power System (IPS) Switchboard

The modular design of Siemens **Integrated Power System (IPS) switchboard** allows the customer to integrate electrical distribution equipment, power monitoring, and environmental controls that typically mount in multiple enclosures into one switchboard line-up. Customers have the freedom to configure an arrangement that best fits their needs. Optional factory installed interconnection wiring is available to further reduce installation time.

IPS switchboards consist of one service section and one or more distribution sections that are cable connected. However, IPS switchboards are also available with through bus and pull sections. IPS switchboards accommodate systems up to 6000 amps incoming, 600 VAC maximum.

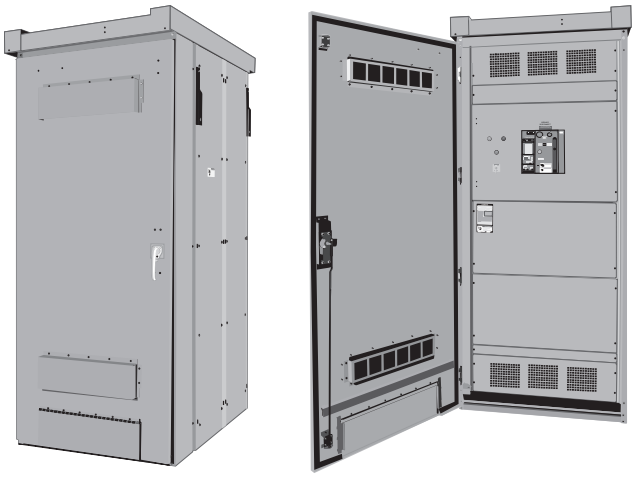


Service Section

Distribution Sections

Generator Ready, Quick Connect Switchboard

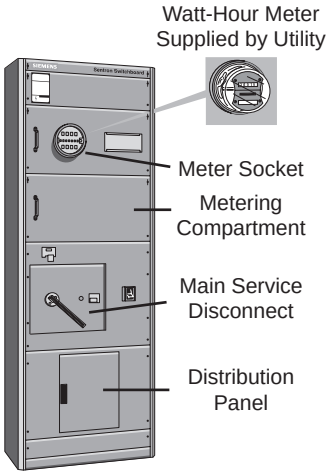
Siemens **Generator Ready, Quick Connect Switchboard** meets the market need for quick connection of a generator for temporary back-up power.



Generator Ready Switchboard in NEMA 3R Enclosure

Super Blue Pennant Switchboard

Siemens **Super Blue Pennant switchboard** is a service entrance switchboard with main service disconnect and distribution devices contained in a single unit that meets **Electric Utility Service Equipment Requirements Committee (EUSERC)** specifications. These switchboards are rated for 400, 600, or 800 amps with a circuit breaker main and 400 or 600 amps with a fusible Vacu-Break switch main.

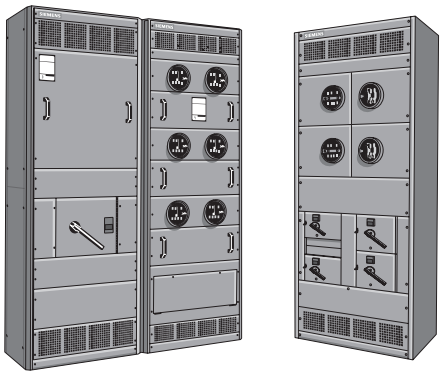


Commercial Multi-Metering Switchboards

Siemens **commercial multi-metering switchboards** are designed for applications where multiple utility meters are required. These applications include shopping centers, office buildings, and other buildings with multiple tenants.

Siemens **SMM switchboards** are designed to meet EUSERC specifications. The switchboard main service is rated up to 4000 amps for the following services: 120/240 V 1-phase, 3-wire; 240/120 V 3-phase, 4-wire, 208Y/120V 3-phase, 4-wire; and 480Y/277 V 3-phase, 4- wire.

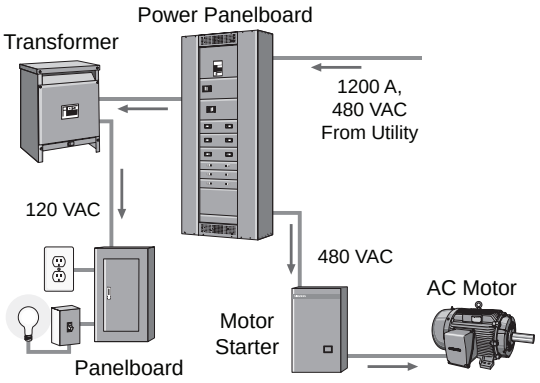
Siemens **MMS switchboards** provide a high-quality, multi-metering solution for areas where EUSERC compliance is not necessary. The switchboard main service is rated up to 4000 amps for the following services: 208Y/120V 3-phase, 4-wire and 480Y/277 V 3-phase, 4- wire.



SMM Switchboard MMS Switchboard

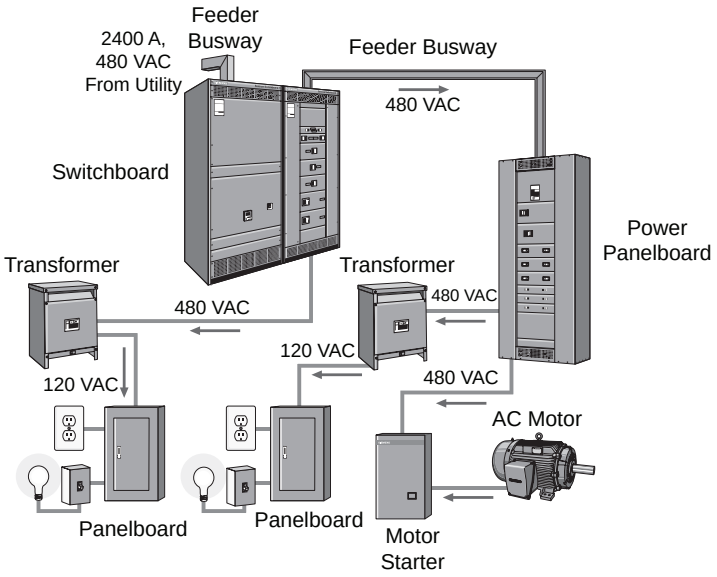
Panelboard Example

When deciding between a panelboard and a switchboard in commercial applications, it is not always clear which product you should chose. In the following small commercial application example, up to 1200 amps at 480 volts is supplied by the utility to a power panelboard. Multiple circuits are used to supply power throughout the facility. For simplicity, only a few devices are shown. For example, one circuit is used to supply power through a transformer to a lighting and appliance panelboard which controls lighting and electrical outlets. Another circuit supplies power to a motor through a motor starter.



Switchboard Example

In larger or more demanding commercial applications, switchboards are often used to distribute power. In the following example, up to 2400 amps at 480 volts is applied to the service section of a switchboard. For simplicity, only a few devices are shown. For example, one circuit supplies power through a transformer to a lighting and appliance panelboard which controls lighting and electrical outlets. Another circuit supplies power to a power panelboard located further away or on another floor. This power panelboard supplies power to a motor and to a lighting and appliance panelboard.



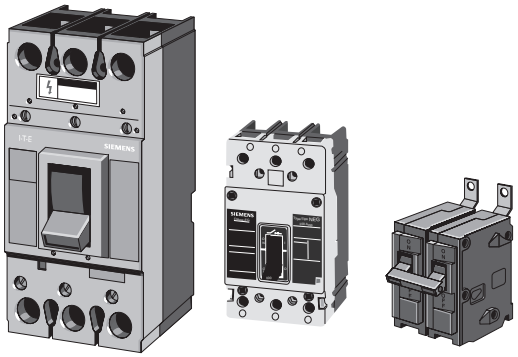
From the limited information provided in the two previous examples, except for the maximum service current requirement, it is not obvious whether a power panelboard or a switchboard should be used at the service entrance. This determination is usually made by the customer or a consulting engineer based on the overall requirements of the application. The service entrance and other application requirements are then detailed in **specifications** communicated to potential suppliers in a **request for proposal (RFP)**.

Circuit Breakers

Circuit breakers are used in panelboards and switchboards to provide automatic circuit protection and a manual means of energizing and de-energizing a circuit. Like the residential circuit breakers previously discussed, most circuit breakers used in commercial applications in the United States are **molded case circuit breakers (MCCBs)** which conform to NEMA AB1 and UL 489 specifications.

The circuit breakers used in residential applications and many of the circuit breakers used in commercial applications are **thermal-magnetic circuit breakers**. Thermal-magnetic circuit breakers are so named because they have a trip unit that trips for an overload condition when it gets too hot and trips immediately when it magnetically senses a short circuit.

Siemens offers a variety of molded case circuit breakers with thermal-magnetic trip units and current ratings up to 2000 amps.



Molded Case Circuit Breakers with Thermal Magnetic Trip Units

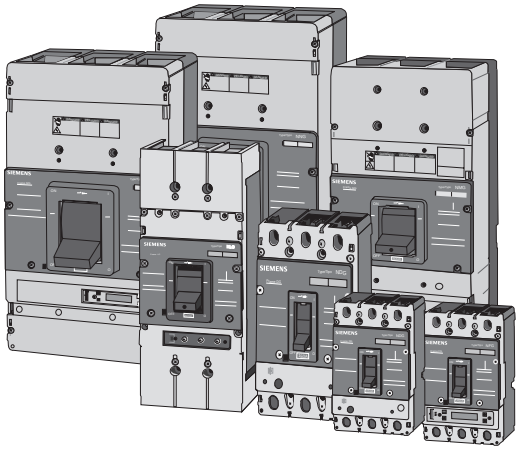
In many commercial applications, it is necessary to coordinate circuit breaker tripping so that the downstream circuit breaker closest to a fault trips first, and breakers upstream only trip when necessary. Proper coordination reduces the likelihood of nuisance tripping or more extensive power outages than necessary in response to a fault. Trip coordination requires appropriate selection of circuit breakers and other circuit protection devices. In addition, circuit breakers with adjustable trip characteristics can be used.

While some thermal-magnetic circuit breakers have an adjustable trip curve, the adjustment is limited. Circuit breakers with a **solid state trip unit**, on the other hand, typically have multiple adjustments.

In the past, choosing the variety of circuit breaker types needed for many applications required selection of circuit breakers with varied designs, locking users into extensive spare parts requirements. In response to this problem, Siemens developed the VL global family of molded case circuit breakers.

VL Circuit Breakers

Siemens **VL circuit breakers** have a modular design that provides maximum flexibility. VL circuit breakers are available with continuous current ratings up to 1600 amps. Each circuit breaker frame is compatible with three trip unit models, **Model 525 Thermal-Magnetic Trip Unit**, **Model 555 Electronic Trip Unit**, and **Model 586 Electronic Trip Unit with Liquid Crystal Display (LCD)**. In addition, only two families of common internal accessories are needed to cover the complete range of VL breakers.



VL Circuit Breakers

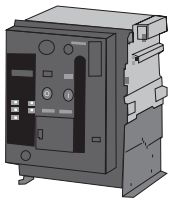
WL Circuit Breakers

The circuit breakers discussed thus far in this course are molded case circuit breakers that conform to the UL 489 specification. This specification also covers a category of molded case circuit breaker commonly referred to as an **insulated case circuit breaker (ICCB)**. ICCBs are generally used in switchboards and may be fixed mounted or drawout mounted.

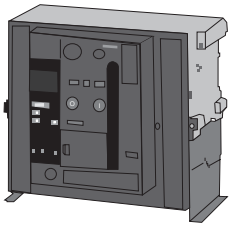
Another category of large circuit breakers is the **low voltage (LV) power circuit breaker**. LV power circuit breakers are generally drawout mounted and may be used in switchboards or switchgear. LV power circuit breakers intended for use in the United States conform to **IEEE** standards (C37.13, C37.16, C37.17, and C37.50). The corresponding UL specification for LV power circuit breakers is UL 1066.

Siemens WL modular family of circuit breakers includes both ICCBs that conform to the UL 489 specification and LV power circuit breakers that conform to UL 1066 and corresponding IEEE specifications.

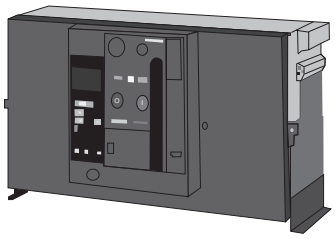
Frame Size I



Frame Size II



Frame Size III

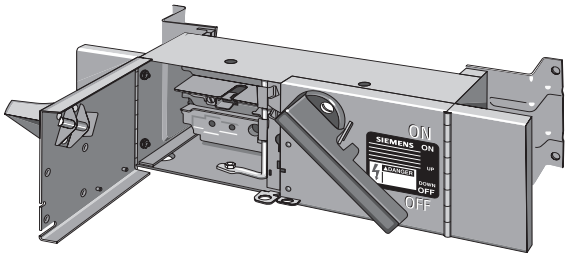


WL UL 489 circuit breakers have a rated maximum operating voltage of 600 V and are available in three frame sizes with frame ratings from 800 to 5000 amps. All three frame sizes have fixed-mounted and drawout-mounted versions.

WL UL 1066 circuit breakers are generally used in low voltage (LV) switchgear as drawout-mounted breakers, have a rated maximum operating voltage of 635 V, and are available in two frame sizes with frame ratings from 800 to 5000 amps.

Vacu-Break Fusible Switches

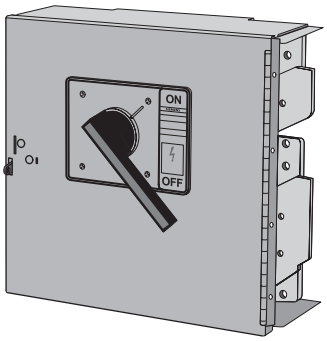
A fusible disconnect switch is another type of device used in panelboards and switchboards to provide overcurrent protection. Properly sized fuses, located in the switch, open when an overcurrent condition occurs. Siemens **Vacu-Break fusible switches** are available with continuous current ratings up to 1200 amps.



HCP Fusible Switches

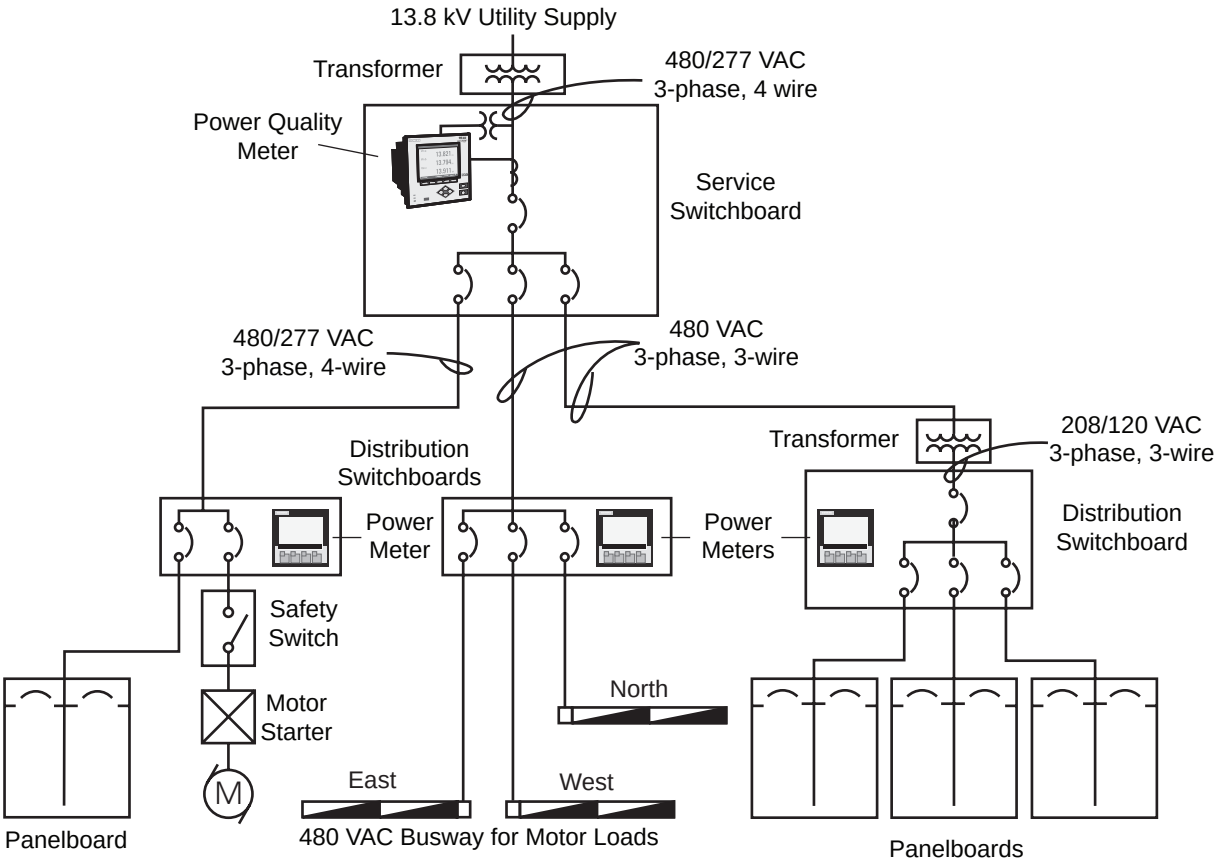
Siemens **high contact pressure (HCP) fusible switch** is another device that can be used as a disconnect device in panelboards and switchboards. Visible contacts provide a visual indication concerning the state of the switch before servicing. HCP fusible switches are available with ampere ratings from 400 to 1200 amps.

HCP fusible switches are suitable for use on systems with up to 200,000 amps of available fault current when used with class J or class L fuses.



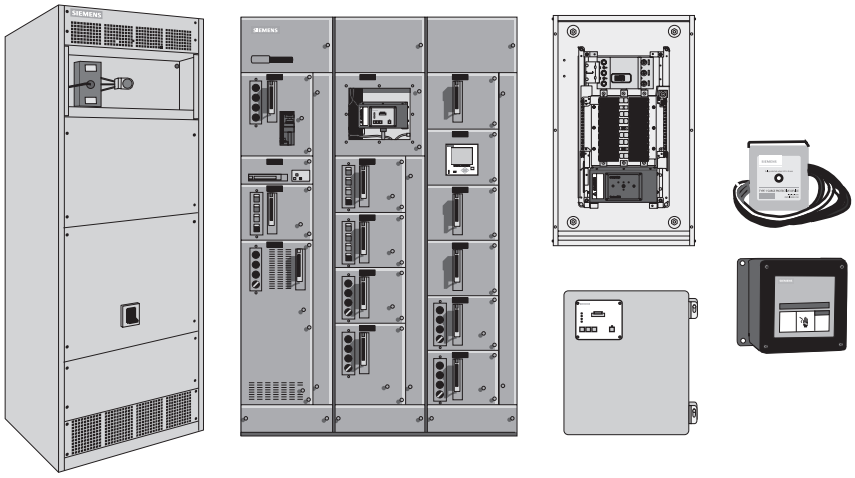
Power Monitoring Systems

Siemens offers a full line of **power meters** and related components and software to monitor critical loads, power quality, and demand.



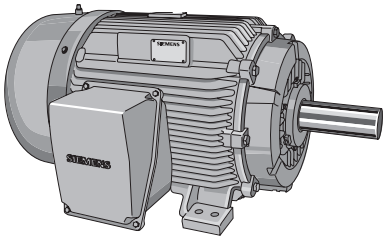
Transient Protection System (TPS3)

Many types of equipment, especially computers and office equipment, are susceptible to the high energy levels associated with electrical surges, which can be caused by lightning or electrical equipment operation. Any component between the source of the surge and ground can be damaged. In response to this problem, Siemens **Transient Protection System (TPS3)** offers UL 1449 3rd edition **surge protection devices (SPDs)** to fit every level of the electrical distribution system.



AC Motors

AC motors are used in commercial applications for fans, pumps, elevators, escalators, and conveyors. In the United States, these motors usually conform to NEMA specifications. Siemens offers a variety of NEMA motors in two efficiency levels. Siemens **NEMA Premium Efficient motors** meet NEMA Premium efficiency standards and our **Ultra Efficient motors** with our exclusive die cast copper rotor technology exceed NEMA Premium efficiency standards.



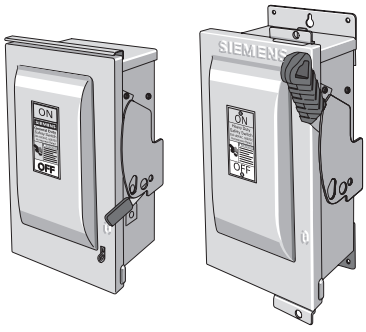
VBII Safety Switches

A safety switch is a type of enclosed switch. Fusible safety switches include provisions for fuses, non-fusible safety switches do not. **Siemens VBII safety switches** are available in **general duty**, **heavy duty**, and **double throw** designs.

A common use for a single throw safety switch is to provide a disconnecting means and fault protection for a motor circuit. A double throw safety switch, on the other hand, is used to transfer a load from one power source to another or to connect a single power source to either of two loads.

General duty VBII switches are intended for applications where reliable performance is needed, but duty requirements are not severe, and voltage ratings above 240 VAC are not required. General duty VBII switches are available with continuous current ratings from 30 to 600 amps.

Heavy duty VBII switches provide the rugged construction needed for more severe applications and are available with voltage ratings up to 600 V AC or DC and continuous current ratings from 30 to 1200 A.

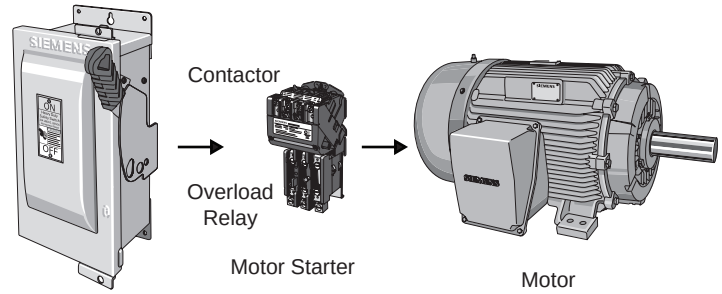


General Duty Heavy Duty

VBII Safety Switches

Motor Starters

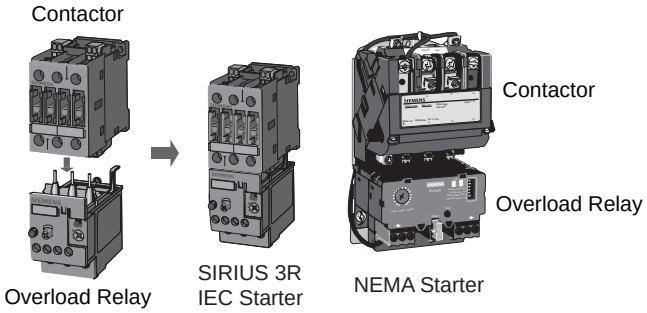
Although safety switches can be used to start and stop motors, many motor applications require the use of remote control devices to start and stop the motor. Motor starters are commonly used to provide this function. In addition, some motor starters have multi-speed and reversing capability. When the motor starter is contained in the same enclosure with a fusible disconnect switch or circuit breaker, it is referred to as a **combination starter**.



A **motor starter** typically consists of a **contactor** and an **overload relay**. A contactor is an electromagnetic device with contacts that control power to a motor. An overload relay prevents damage to a motor by automatically stopping the motor when an overload occurs.

Pushbuttons and other types of control components are used in the control circuit for a motor starter to energize and de-energize the contactor and perform other functions.

Siemens manufactures a variety of motor starters and other control components. Some of these components, such as those that are part of our **SIRIUS Modular System**, are manufactured to **International Electrotechnical Commission (IEC)** specifications. Siemens also manufactures a full range of control products that conform to NEMA specifications.



Review 2

1. Siemens P1 panelboards are available with current ratings up to _____ amps.

2. Siemens P5 panelboards are available with continuous current ratings up to _____ amps for main breaker, main switch, and main lug only panels.

3. Siemens SB1 switchboards have through bus ratings up to _____ amps at 600 VAC.

4. The modular design of Siemens ____ switchboard allows the customer to integrate electrical distribution equipment, power monitoring, and environmental controls that typically mount in multiple enclosures into one switchboard lineup.

5. Siemens ___ circuit breakers have a modular design which allows each circuit breaker frame to be compatible with any of three trip unit models.

6. Siemens ___ circuit breakers are available either as an insulated case circuit breaker or as a low voltage power circuit breaker.

7. Siemens VBII safety switches are available in _____ duty, _____ duty, and _____ designs.

Industrial Applications

Voltage Classes

The power distribution equipment discussed thus far is often referred to as low voltage equipment, but there are different definitions for low voltage and other voltage classes. For the purposes of this discussion of power distribution equipment, **low voltage (LV) systems** operate at 1000 volts (1 kV) or less and **medium voltage (MV) systems** generally operate between 1000 and 38,000 volts (1 to 38 kV).

The power requirements of many industrial facilities can be accommodated using only LV systems. In many instances, however, MV equipment, especially at the service entrance, is required. Electric utilities, which must provide power to customers of various types, use transmission systems that operate in the high voltage or extra high voltage range, but it is beyond the scope of this course to discuss these systems.

Within the United States, Siemens products and services are provided by a number of operating companies, including Siemens Industry, Inc. (SII). Each operating company provides the products and services needed for its customer base. The Siemens operating company that supplies power generation, transmission, and high-voltage distribution equipment and services to electrical utilities is appropriately named **Siemens Energy**.

Because many industrial, and some commercial and institutional, customers served by SII also have significant power distribution needs, SII sells a variety of products such as: power transformers, surge arresters, instrument transformers, protective relays, substation automation, and MV switchgear, As important as these products are, it is not within the scope of this course to cover all these systems. It is worthwhile, however, to briefly discuss MV switchgear.

Switchgear

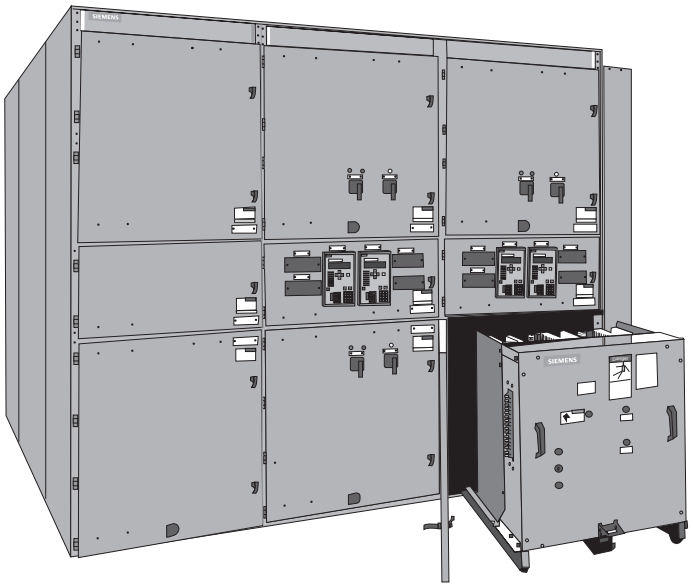
The term **switchgear** is used to describe a compartmentalized system of coordinated devices used for power distribution control and circuit protection. Essentially, switchgear performs the same function as the switchboards previously described, but different standards dictate the design of switchgear. In addition, because MV switchgear must handle higher levels of electrical energy and be capable of interrupting higher fault currents, it is larger and more heavily constructed.

A large industrial facility receives electrical power at a substation from the utility company at high transmission voltage levels. The voltage is stepped down to a medium voltage level at the substation for distribution throughout the facility. Large industrial facilities can be spread out over several acres and may incorporate many large buildings. Multiple MV switchgear units, often called **MV metal-clad switchgear**, could be used if the power demand is large enough.

GM-SG Air Insulated Metal-clad Switchgear

Siemens manufactures multiple types of MV switchgear to meet varied customer requirements. This includes MV air insulated equipment and gas insulated equipment with voltage ratings up to 38 kV. One example of a widely used MV switchgear product is **Siemens GM-SG medium voltage (5 to 15 kV) air insulated switchgear.**

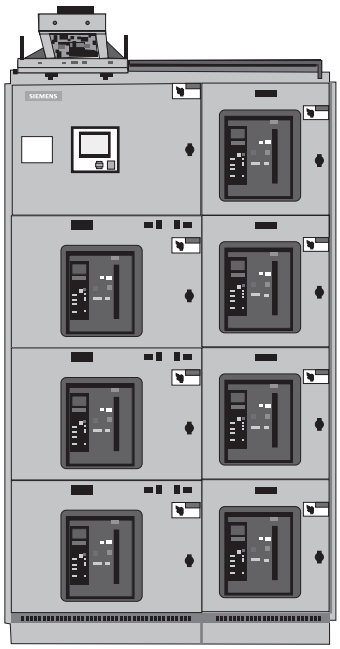
GM-SG MV switchgear is available in arc resistant and non-arc-resistant versions. It features Siemens globally proven 3AH3 circuit breaker operator which provides higher interrupting ratings, faster interrupting times, and reduced maintenance requirements.



WL Low Voltage Metal-Enclosed Switchgear

WL low voltage metal-enclosed switchgear is manufactured by SII and incorporates WL low voltage power circuit breakers. WL low voltage switchgear is similar to Siemens switchboard products, which can also employ WL circuit breakers. However, WL low voltage switchgear conforms to IEEE and UL standards that differ from NEMA and UL switchboard standards.

A WL switchgear assembly consists of one or more metal enclosed vertical sections. The end sections are designed to allow installation of additional sections. Each vertical section consists of up to four individually enclosed breaker or auxiliary compartments. WL switchgear has horizontal bus rated for 6000 amps maximum and vertical bus rated for 5000 amps maximum.



Siemens WL Arc Resistant Low Voltage Switchgear

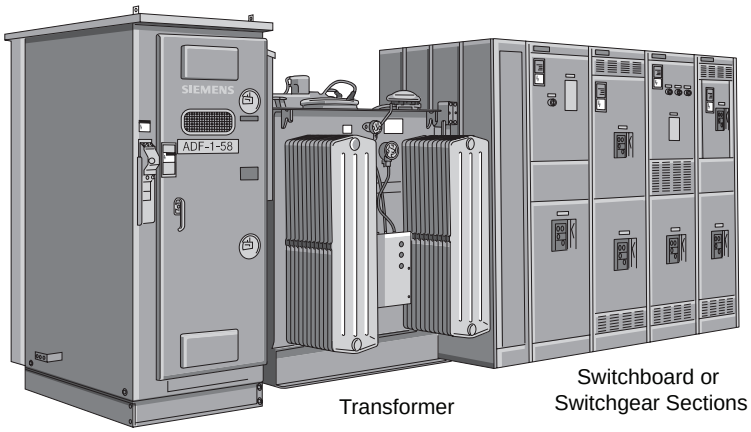
In recent years, many customers have become more aware of the potential hazards to personnel posed by arc flashes. An **arc flash** is a condition that occurs as a result of a high energy arc fault where heat energy is suddenly and often explosively produced. **WL arc resistant low voltage switchgear** is designed, constructed, and performance tested to IEEE C37.20.7-2007. This means that It provides an additional degree of protection from the hazards associated with internal arc faults.

WL arc resistant low voltage switchgear uses WL low voltage power circuit breakers and has a maximum internal arcing short-circuit current rating of 100 kA at 580V and 85 kA at 635V and a maximum arcing duration of 500 msec.

Secondary Unit Substations

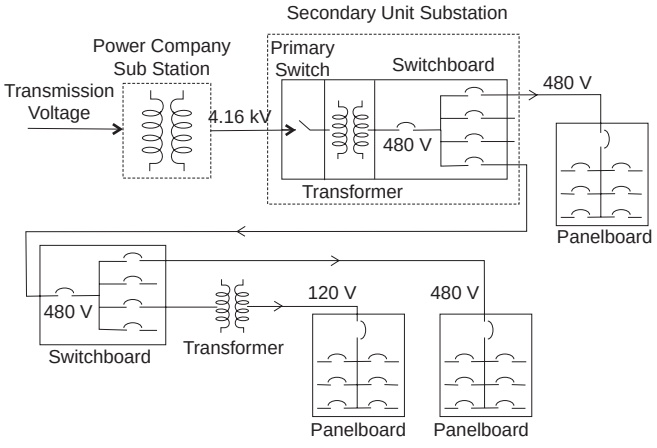
Some customers require an integrated assembly, called a **secondary unit substation**, to provide electrical service to a facility. A secondary unit substation consists of a primary switch and one or more transformers mechanically and electrically connected to switchboard or switchgear sections. All elements of the substation are engineered to the specific needs of the application.

The incoming service to the primary switch is typically rated for 2.4 to 13.8 kV. The primary switch is used to connect and disconnect the secondary unit substation from the incoming service. The transformer section can be liquid filled, ventilated dry type, or cast coil type and is used to step down the voltage to below 600 volts. The outgoing section can be switchboard or WL low voltage switchgear sections.



Small Industrial Facility Power Distribution Example

An example of the power system for a small industrial facility is one shown in the following illustration. For simplicity, only a few circuits are shown. In this example, incoming voltage is stepped down to 4160 volts and applied to the facility's secondary unit substation. A transformer in the secondary unit substation steps the voltage down to 480 volts which is distributed to various switchboards and panelboards. A 1-phase transformer reduces the voltage to 120 volts.

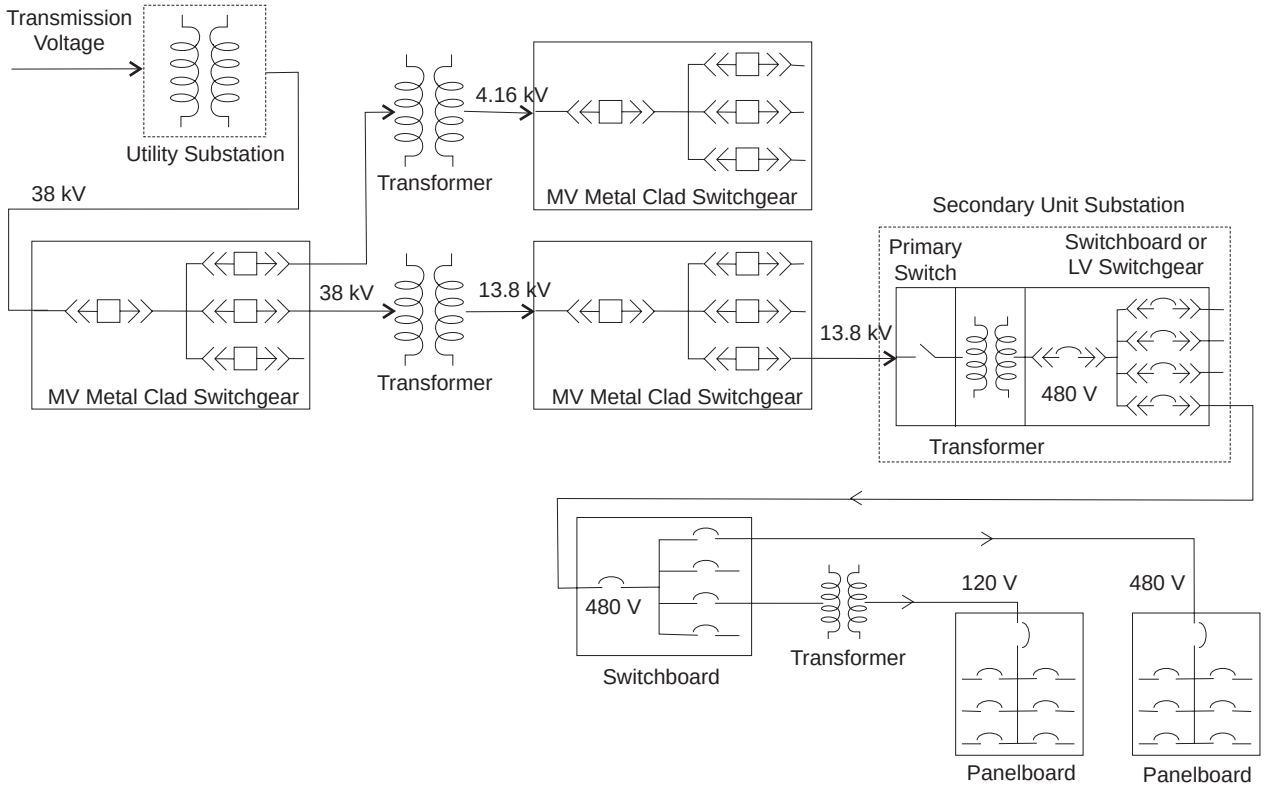


Large Industrial Facility Power Distribution Example

Even in large industrial facilities, supply voltage must be reduced to a level that can be used by most electrical equipment. While some machines require voltages above 480 volts, most factories use AC motors, drives, motor control centers, and other devices that operate on 3-phase, 480 volts and other equipment that requires even lower 1-phase or 3-phase voltages.

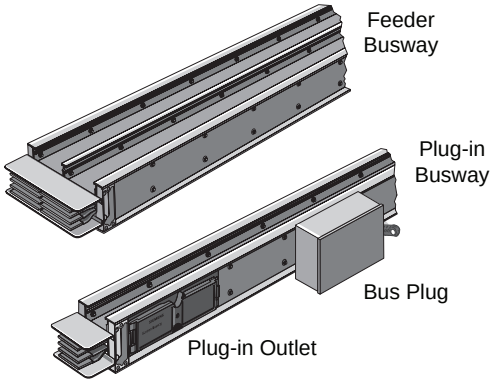
In the example shown in the following illustration, power is stepped down at the utility company's substation to 38,000 volts and applied to the incoming section of the industrial plant's 38 kV medium voltage metal-clad switchgear.

One distribution branch is stepped down to 4160 volts and another to 13,800 volts and further distributed through MV metal clad switchgear units. A 13,800 volt branch is applied to a secondary unit substation and further reduced to 480 volts. Further down this path, a 1-phase transformer reduces the voltage to 120 volts.

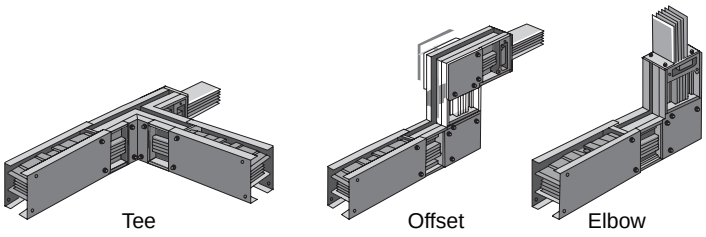


Busway

Busway is widely used in industrial applications to distribute power. There are different types of busway, however. **Feeder busway** is used to conduct feeder current to loads that are sometimes remote from the power source. **Plug-in busway**, on the other hand, incorporates plug-in units, called bus plugs, to allow loads to be distributed over the length of the run. Many industrial applications require both types of busway.

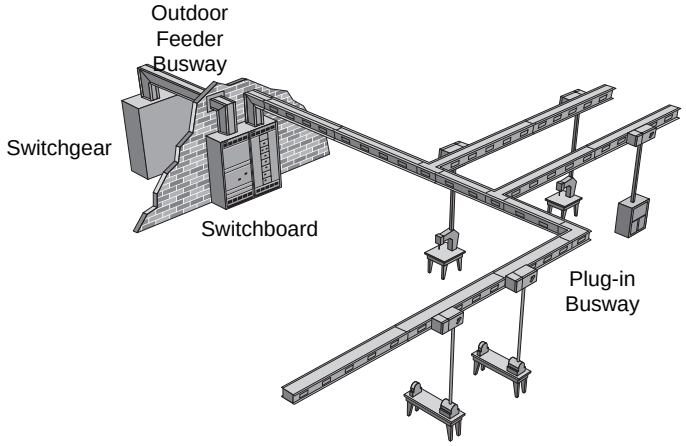


In addition to straight sections, busway runs also include a number of components such as **tees**, **offsets**, and **elbows** used to route busway through the facility.



Busway Example

In the following example, busway is used to transfer power from switchgear located outside a building to a switchboard located inside a building. Electrical power is then distributed to various locations in the industrial facility.



Siemens Busway

Siemens manufactures a variety of busway types to meet varied application requirements.

SENTRON Busway is a flexible power distribution solution with an easy-to-install single bolt joint stack design, optional 200% neutral or isolated ground, and ratings from 225 to 5000 amps.

XJ-L Busway is well known for its outstanding performance, providing convenient, cost-effective power distribution for high-tech environments, data centers, laboratories, and other applications requiring consistent, quality power distribution. To meet changing demands of the industry, XJ-L has been reengineered to provide even more options and modularity and is now called **XJ-L High Density (HD) Busway**. XJ-L HD Busway is engineered for high reliability with optional isolated grounding, 200% neutral, and ratings of up to 400A.

XL-U Busway is well-suited for voltage sensitive, heavy-duty welding applications. Available in ratings from 225 to 6500 amps, XL-U Busway is a reliable solution for automotive and other industrial applications.

BD Busway features a rugged, air-insulated design with an over 70-year track record that includes thousands of installations in operation today.

Review 3

1. Siemens _____ medium voltage air insulated switchgear features the globally proven 3AH3 circuit breaker operator.

2. Each section of Siemens WL low voltage switchgear consists of up to ____ individually enclosed breaker or auxiliary compartments.

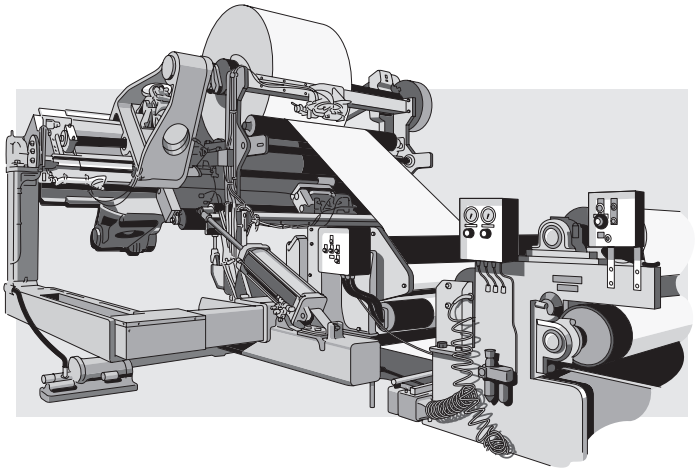
3 A _____ consists of a primary switch and one or more transformers mechanically and electrically connected to switchboards or switchgear sections.

4. _____ busway is used to conduct current to loads that are sometimes remote from the power source. _____ __ busway allows loads to be distributed over the length of the run.

5. Siemens _____ busway features an easy-to-install single bolt joint stack.

Manufacturing Applications

Thus far, this course has primarily centered on Siemens products used to distribute power throughout residential, commercial, and industrial applications. In all these applications, this electrical energy is also used for lighting, heating, air conditioning, office equipment, and other non-industrial systems. Unlike commercial and residential applications, however, in industrial applications most of the electrical energy is used to power manufacturing equipment.



The equipment used in manufacturing varies widely depending upon the volume of production and the types of processes employed. As a result, Siemens offers a vast array of products for use in virtually every phase of manufacturing. Many of these products are purchased by machine builders or **OEMs (original equipment manufacturers)** for resale to the end user. In other cases, the end user may engineer a machine or process line or employ another company to do the engineering. The end result, however, is a coordinated system or process.

There are a variety of ways to represent manufacturing processes. However, since the goal of this course is to present an overview of Siemens Industry, Inc. products, we need only take a high-level view of manufacturing processes.

In general, we can say that most manufacturing processes incorporate one or more of the following process types:

Discrete Parts Manufacturing
Assembly
Batch Processing
Continuous Processing

The process type included in the overall manufacturing process depends upon the products being produced. Some industries, for example, are dominated by a specific process type.

Process Type	Industry Examples
Discrete Parts Manufacturing	Aircraft Parts Automotive Parts Electrical & Electronic Parts
Assembly	Aircraft Motor Vehicle Computer
Batch Processing	Food & Beverage Pharmaceutical
Continuous Processing	Chemical Petroleum

As an aid to understanding SII products, the next section of this course provides examples of products that could be used in each of the process types previously listed. Given the number and diversity of SII products, only representative examples are used.

Discrete Parts Manufacturing

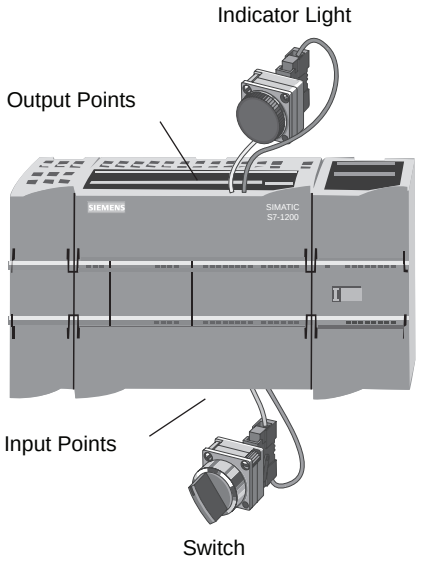
Manufacturing discrete parts typically requires the use of multiple machines. Machines are used to move and store raw materials, transform raw materials into finished parts, package and store parts, prepare parts for shipment, and a host of related activities.

Totally Integrated Automation (TIA)

Although the various machines used in this process differ, a typical machine needs some type of control system. In the past, designing a control system, even for a relatively basic machine, required an extensive engineering effort to make the various components interact fluidly. Now with Siemens **Totally Integrated Automation (TIA)**, compatible components and systems are available for use in control systems of all sizes. Although TIA encompasses many types of devices, **SIMATIC controllers** are perhaps the backbone of the system.

PLC-controlled Machine

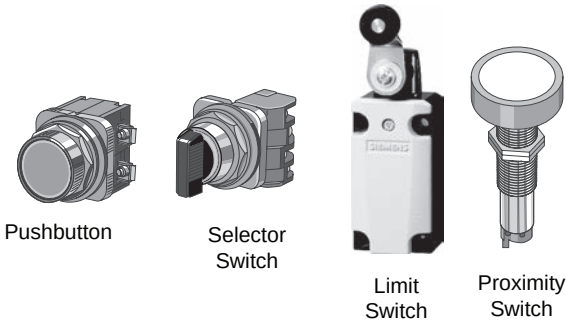
One example of a SIMATIC controller is an **S7-1200 programmable logic controller (PLC)**. A PLC is an industrial computer that interconnects to the machine it is controlling largely through its **input-output (I/O) system**. The PLC's I/O system allows it to receive inputs from switches and sensors and generate outputs to actuating devices, such as contactors and solenoids, and display devices, such as indicator lights.



SIMATIC S7-1200

Input Devices

The PLC receives signals from various switches and sensors in the controlled machine or related equipment. Many of these signals are on/off type conditions, also called **discrete** or digital signals. In some cases, the signals come from manual devices such as pushbuttons and selector switches. However, many discrete PLC inputs come from devices, such as limit switches or proximity switches, that are turned on and off by machine operations.

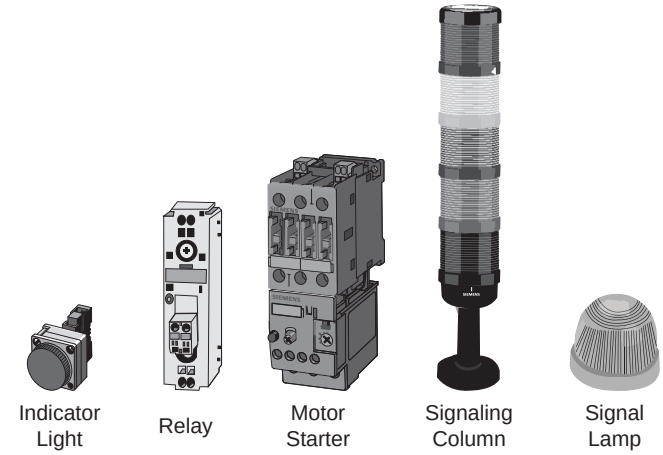


In addition to discrete inputs, the PLC may also receive **analog** inputs from sensors that vary voltage or current as conditions in the machine or related equipment vary.

Inputs, as well as the current condition of PLC outputs and internal data values, are analyzed by the PLC as it executes its stored program. The PLC uses this process to determine the signals it sends to output devices that control the operation of the machine or indicate machine conditions.

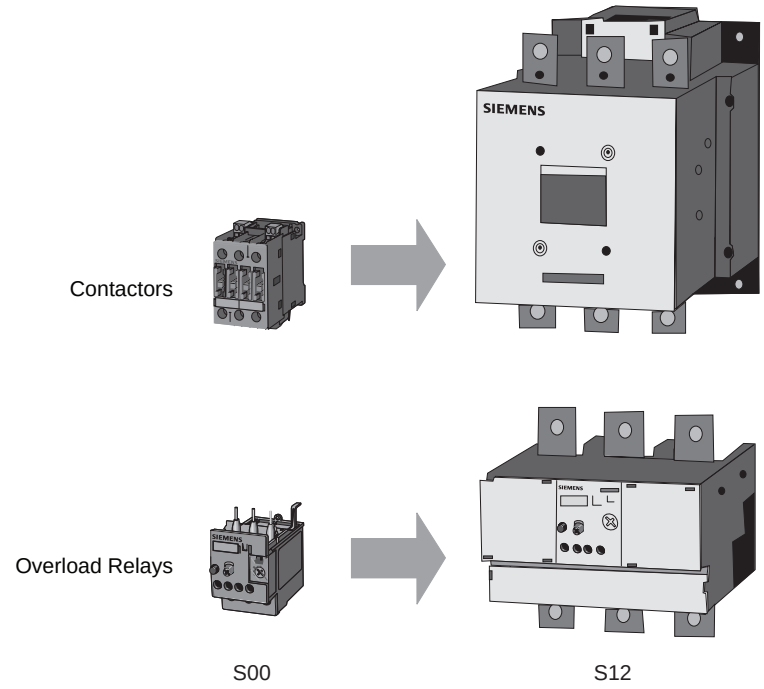
Output Devices

Just as some inputs are analog type inputs that vary in current or voltage, some outputs are analog type as well. Many outputs, however, are discrete (on/off) signals. In some cases, these signals control equipment directly. In other cases, an intermediate device, such as a control relay or motor starter, is used. The following illustration shows a few examples of the types of devices that may be controlled.



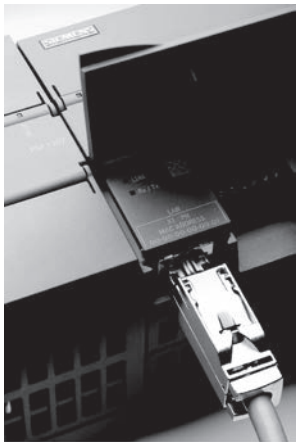
SIRIUS Modular System

Siemens manufactures an extensive array of components and systems that can be utilized for machine control applications. One such system is the **SIRIUS modular system** of industrial controls which incorporates components in each of the following categories: switching, protecting, starting, monitoring and controlling, detecting, commanding and signaling, and supplying. Where varied power requirements are needed, the SIRIUS modular system provides a range of options. For example, contactors and overload relays are available in multiple sizes ranging from size S00 to S12.



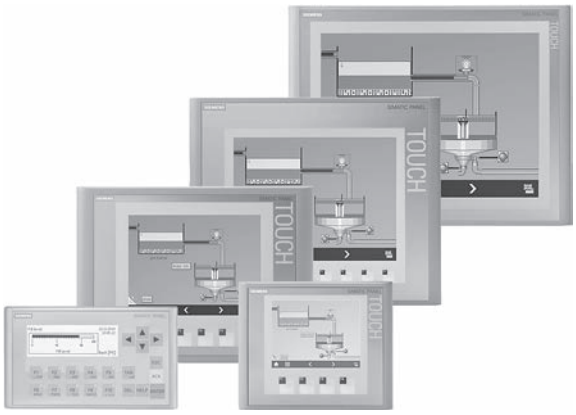
Communication

In addition to signals provided to a PLC through its I/O system, a PLCs often also communicates with other devices via one or more communication ports. Communication ports provide a pathway for the PLC to communicate with devices such as operator interfaces, variable speed drives, computers, and other PLCs.



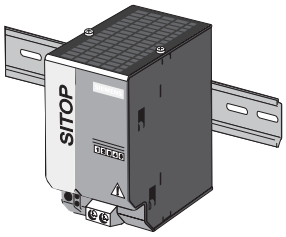
Human Machine Interface

A **Human Machine Interface (HMI)** is any device that acts as a link between the operator and the machine. Typically, however, the term HMI refers to devices that display machine or process information and provide a means for entering control information. Siemens **SIMATIC HMI** products provide a range of options from the operator control and monitoring devices and visualization software needed for machine-level interfaces to scalable systems for plant-wide process control.



SITOP Power Supplies

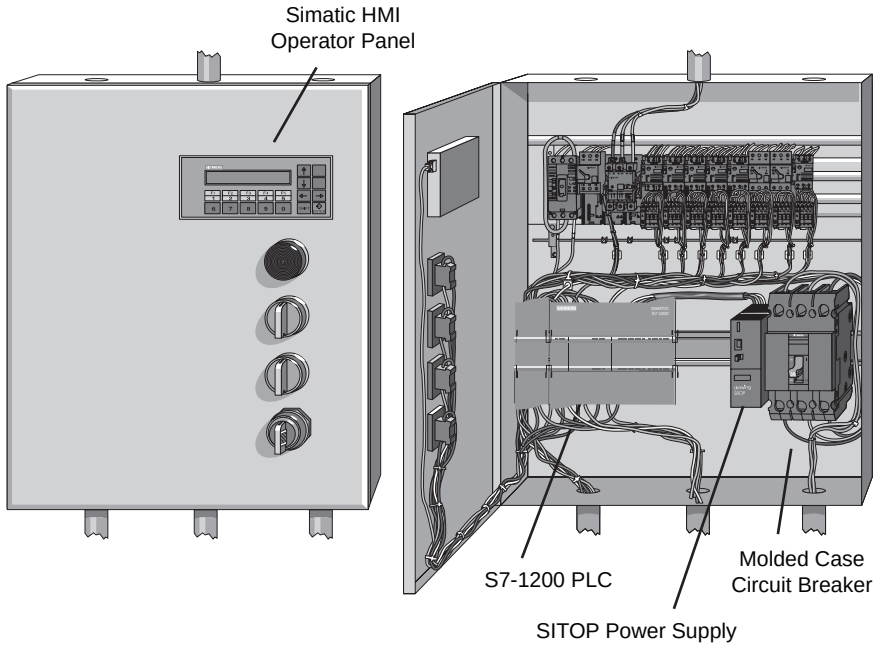
Often control components of various types require a regulated power supply. Siemens offers a range of **SITOP** regulated 24 VDC power supplies. In addition, options for additional voltages are also available.



Machine Control Example

In the following machine example, an S7-1200 PLC is mounted in a machine's control panel. The manufacturer of the machine has chosen to use field devices that require 24 VDC power. The power for the field devices and the PLC is provided by a SITOP power supply, shown adjacent to the S7-1200 PLC.

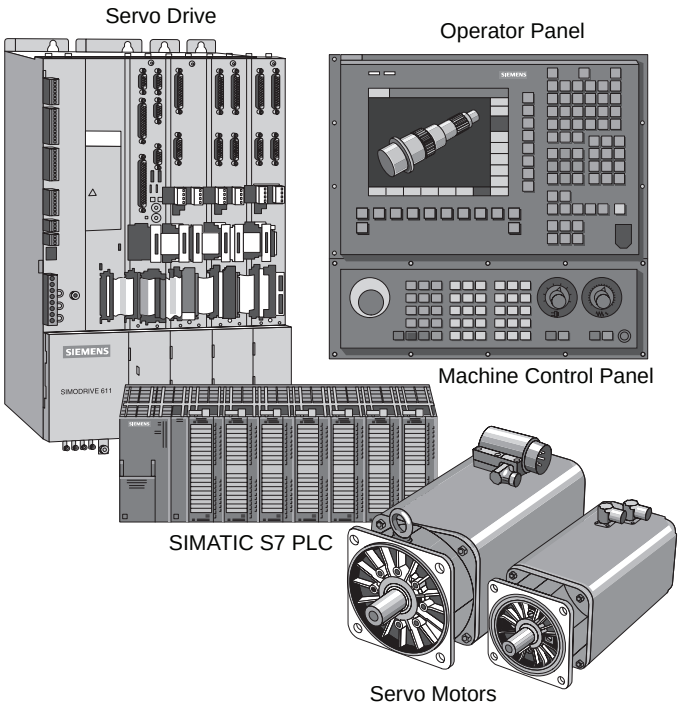
As the S7-1200 PLC executes its control program, it receives inputs from manual switches mounted on the front of the panel. It also communicates with a SIMATIC HMI operator panel that provides for manual inputs from the machine operator or maintenance person and displays alphanumeric messages indicating machine status. The PLC also receives inputs from other control devices such as limit switches or proximity switches that change state as a result of machine operations. In this example, the PLC controls relays, contactors, and other devices that turn on and off to control various aspects of the machine.



Computer Numerical Controls (CNC)

PLCs are not the only control systems used for machines. Consider, for example, the type of control system required by machine tools, such as lathes, grinding machines, punch presses, and machining centers. Machine tool control systems typically incorporate a PLC, a **computer numerical control (CNC)**, and related components such as **servo drives** and **servo motors**. CNC machine tools are used to cut or machine to complex and exacting specifications.

Siemens offers a range of **SINUMERIK CNC** models, which includes models for basic machines, dynamic machining, high-speed machining, and PC-based CNC. In addition, Siemens offers compatible servo drives and servo motors as well as other motion control components and systems. These products provide the coordinated multi-axis control needed for milling, drilling, turning, grinding applications, and other applications.



Review 4

1. An example of a device that might be controlled by a PLC discrete output is a _____.

   a. limit switch
   b. relay
   c. proximity switch
   d. selector switch

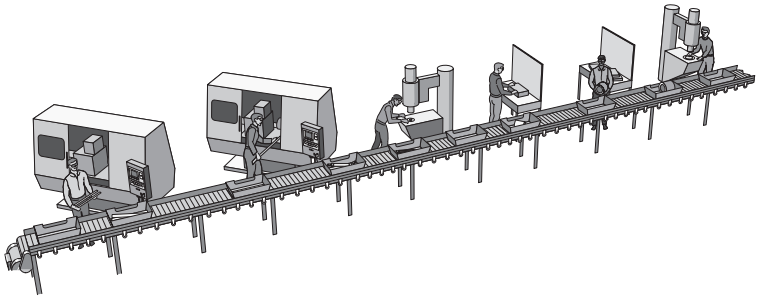
2. The _____ modular system of industrial controls incorporates components in each of the following categories: switching, protecting, starting, monitoring and controlling, detecting, commanding and signaling, and supplying.

3. _____ power supplies are used to provide a regulated DC voltage to power various control components.

4. _____ is a Siemens trade name that includes a range of computer numerical controls used to control machine tools.

Assembly Processes

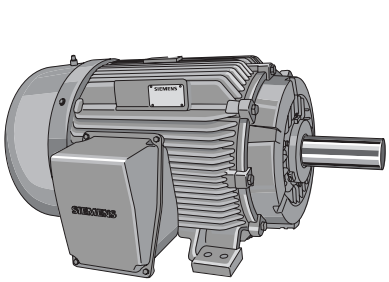
Assembly processes may involve assembling an entire system or subsystem at one location. In many cases, however, parts are mounted sequentially through a series of assembly stations. Units being assembled are moved from station to station via some type of transporter mechanism, such as a conveyor. Any specific assembly station may utilize only manual assembly operations or may include one or more machine operations. The latter is particularly true when just-in-time manufacturing techniques, requiring parts to be manufactured as needed, are employed.



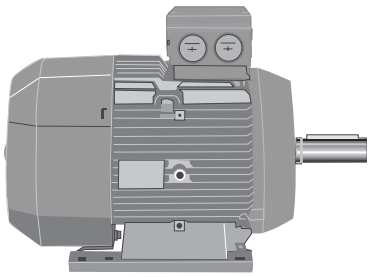
Motors

There are many aspects of assembly processes that are similar to discrete parts manufacturing and, in fact, many factories combine both types of processes. Therefore, it should come as no surprise that the electrical products used in both types of processes are often the same. For instance, AC motors are used in both types of processes to change electrical energy into mechanical energy, the reverse of what a generator does.

In the United States, the most common type of industrial motor is a **NEMA frame size**, three-phase AC induction motor. The term "NEMA frame size" indicates that a motor has frame dimensions that correspond to a **National Electrical Manufacturers Association** specification. Siemens NEMA motor product line includes general purpose motors with light-weight die cast aluminum or rugged cast iron frames as well as severe duty, hazardous duty, inverter duty, and vertical motors. Siemens also manufactures a variety of motors too large to correspond to NEMA frame dimensions **(above NEMA motors)** and motors that comply with **International Electrotechnical Commission (IEC)** specifications.



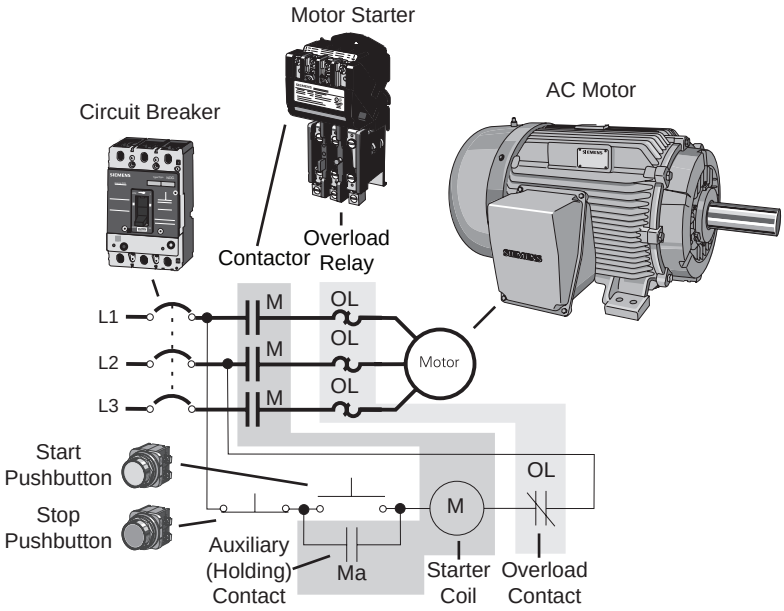
NEMA Motor



IEC Motor

Motor Control

Wherever motors are used, they must be controlled. The most basic type of AC motor control involves turning the motor on and off. This is often accomplished by using a motor starter made up of a contactor and an overload relay. In the example shown in the following illustration, the contactor closes its main contacts and starts the motor when the Start pushbutton is pressed. When the Stop pushbutton is pressed, the contactor opens its contacts and stops the motor. The overload relay protects the motor by disconnecting power to the motor when an overload condition exists. Although the overload relay provides protection from overloads, it does not provide short-circuit protection for the wiring providing power to the motor. For this reason, and because a manual means for disconnecting power is needed near the motor, a circuit breaker used. A safety switch can also be used instead of a circuit breaker.

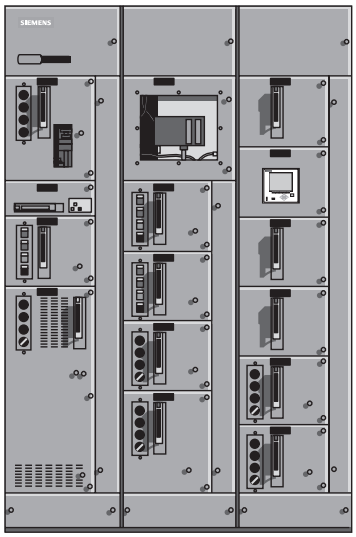


Motor Control Centers

When only a few geographically dispersed AC motors are used, the circuit protection and control components associated with a motor are often installed in an enclosure near each motor. When a larger number of motors are used, these components are frequently concentrated in a motor control center (MCC).

An MCC is a sectionalized structure with control components for each motor mounted in a removable container called a pan or bucket. In addition to combination motor control units, motor control centers can also include items such as reduced-voltage starters, variable speed drives, and PLCs.

Siemens **tiastar MCCs** have been designed to incorporate a variety of Siemens products that offer optimal motor control, communications, monitoring, protection, and automation interfacing. For example, tiastar integrated products can include SIMOCODE motor management systems, SIRIUS 3R reduced voltage starters, and any of several models of Siemens variable frequency drives communicating via the PROFIBUS-DP network. High density and arc flash resistant tiastar MCCs are also available.

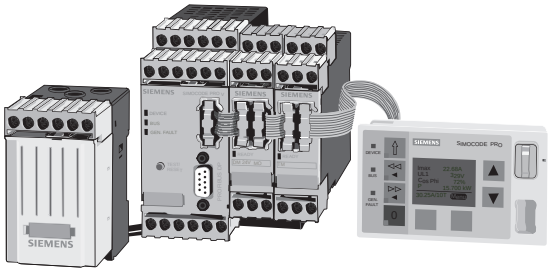


SIMOCODE pro Motor Management System

SIMOCODE pro is a flexible, modular motor management system that provides multifunctional, solid-state protection for constant speed motors. SIMOCODE pro implements all motor protection and control functions; provides for tracking of operational, diagnostic, and statistical data; and communicates with the automation system via PROFIBUS DP.

SIMOCODE pro C is a compact, economical system for full-voltage forward and reversing starters. Each SIMOCODE pro C includes a basic unit connected by a single cable to a current measuring module. An optional operator panel may also be connected to the basic unit.

SIMOCODE pro V is a variable system with an even greater range of functions. In addition to a basic unit, it can include either a current measuring module or a combination current/voltage measuring module, up to five expansion modules, and an optional operator panel (with or without display).

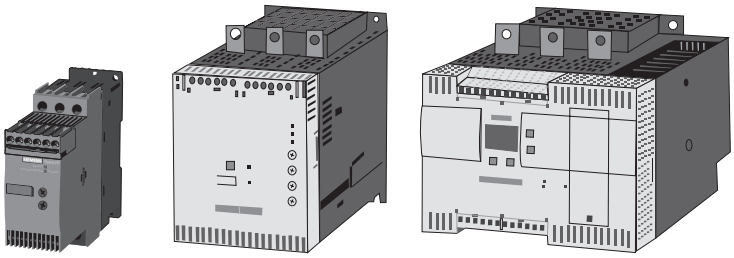


SIMOCODE pro V

SIRIUS 3R Reduced Voltage Starters

While it is common to turn motors on and off instantaneously, this abrupt transition results in power surges and mechanical shock that may need to be avoided, especially when larger motors are involved. Reduced voltage starters, however, apply voltage more gradually. As a result, the motor experiences reduced inrush current and speed is accelerated gradually. There are several types of reduced voltage starters, including solid state reduced voltage starters, called soft starters.

The SIRIUS 3R modular system of components includes **SIRIUS 3RW30** and **3RW40 soft starters** for standard applications, and **SIRIUS 3RW44 soft starters** for high feature applications.



3RW30 3RW40 3RW44

AC Drives

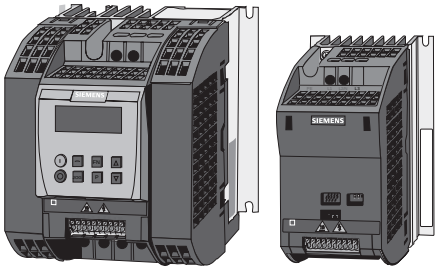
Although motor starters can control an AC motor for constant speed applications, many applications require control of motor speed. An **AC drive** is an electronic device that, in addition to controlling motor speed, may control other quantities such as torque, but that depends upon the capabilities of the drive and the needs of the application. Because the type of motor being controlled is often an AC induction motor and the speed of this motor is dependent upon the frequency of the AC power applied, an AC drive is often referred to as a **variable frequency drive**, or **VFD** for short.

Because AC motors are available in a range of ratings and types and application requirements vary widely, Siemens offers a broad range of AC drives and related products. These drives are divided into two broad classes, low voltage and medium voltage.

Low Voltage AC Drives

Each of these classes is further divided. For example, Siemens low voltage AC drives include general purpose drives, general purpose enclosed drives, high-performance drives, and high-performance enclosed drives. The complete list of Siemens low voltage AC drives is far too extensive to describe in this course, but the following paragraphs provide summary information.

At the low end of the power range is the **SINAMICS G110**, the smallest member of the **SINAMICS** family. The SINAMICS G110 is designed for single phase 200-240 VAC applications up to 4 horsepower (HP).



SINAMICS G110 AC Drives

The SINAMICS family also includes a variety of other **SINAMICS G series** drives for larger general purpose applications as well as **SINAMICS S series** drives designed for high performance applications.

The **MICROMASTER** family, another family of Siemens low voltage AC drives, offers a selection of models covering the power range up to 350 HP.

Medium Voltage AC Drives

Medium voltage AC drives are at the other end of the power range from general purpose AC drives, Siemens is the world's leading supplier of medium voltage AC drives. The performance of our medium voltage drives exceeds even the most demanding application requirements. Siemens offers a lineup of medium voltage AC drives covering the range from 300 to 160,000 HP.

DC Drives

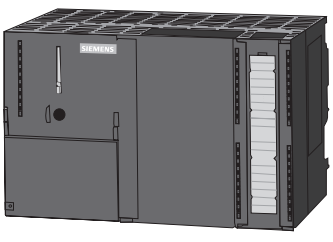
Although AC motors are more commonly used, many factories also use DC motors for selected applications. In many of these applications, precise control of motor speed and torque is required. For these applications Siemens offers the **SINAMICS DC MASTER** family.

Motion Control

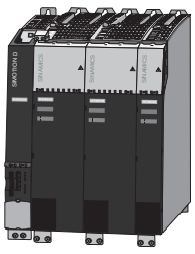
Earlier in this course, you learned that Siemens provides a range of products for use in machine tool control applications. Machine tool applications are not the only applications that require precise motion control. For example, machines used to make plastic, glass, metal, and textile products and machines used for packaging, printing, converting, and transporting also have precision motion control requirements.

In some instances, makers of these machines and systems prefer complete motion control solutions capable of handling varied machine control tasks. In other cases, these customers need specific components, such as high precision drives and motors. In response to these varied requirements, Siemens offers both complete **SIMOTION systems** as well as a variety of precision drives, motors, and related products.

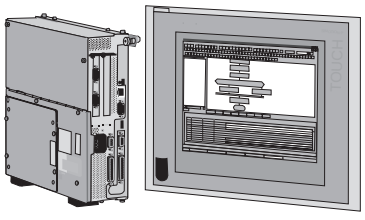
A SIMOTION system consists of three main parts: the hardware platform, runtime software, and engineering software. In addition, three types of SIMOTION hardware platforms are available: controller-based, drive-based, and PC-based.



SIMOTION C
(Controller-Based Platform)



SIMOTION D
(Drive-Based Platform)



SIMOTION P
(PC-Based Platform)

Identification Systems

Assembly applications frequently require identification of objects used or manufactured. This is accomplished by systems that read codes, optical characters, or radio frequency identification (RFID) tags associated with these objects.

Siemens **hand-held and stationary code readers** provide reliable, flexible reading, verification and optical character recognition (OCR).

Siemens **RFID systems** utilize a different technology for sensing objects. For these systems, a mobile data storage unit (tag) is affixed to the object. Each tag stores information associated with the object, or, when the object is a container, the tag may store information about the items in the container. Data stored in tags can be read from or changed by radio frequency (RF) devices. Use of this technology simplifies the process of tracking objects and streamlines the flow of material.

Code Reading Systems

RFID Systems

PLCs

Because assembly processes vary in complexity, the types of control systems and related devices employed also vary. In addition to small- and medium-sized PLCs or other control systems used to control individual machines, one or more larger PLCs may be employed to collect data and coordinate the operation of some or all of the system.

This overall coordination may include control of the full range of motor control devices discussed thus far, from full-voltage starters to precision drives. The specific PLC models used depend on the size and complexity of the application.

Siemens **SIMATIC PLCs** are the foundation upon which our **Totally Integrated Automation (TIA)** concept is based. Because the needs of end users and machine builders vary widely, SIMATIC PLCs are available as conventional modular controllers, embedded automation products, or as PC-based controllers.

A variety of programming options are available. This includes basic programming languages (Instruction List, Ladder Diagram, and Function Block Diagram) as well as more as well as alternative approaches such as S7-SCL (Structured Control Language), S7-Graph, S7-HiGraph, and S7-CFC (Continuous Function Chart).

Modular SIMATIC controllers are optimized for control tasks and can be adapted to meet application requirements using modules for input/output (I/O), special functions, and communications. Examples of products in this category include: **LOGO!, S7-200,** and **S7-1200 micro automation products**, and **S7-300**, **S7-400,** and **S7-1500 modular system PLCs**.

SIMATIC S7-1500

SIMATIC S7-400

SIMATIC S7-1200

SIMATIC S7-300

SIMATIC embedded bundles are a combination of hardware and software, preconfigured for all your automation tasks. Rotary parts are no longer needed, resulting in a system that is extremely rugged with an operating system tailored and optimized for the hardware used. Each embedded system unites the benefits of open PC-based controllers with the ruggedness of conventional controllers.

SIMATIC PC-based controller users rely on the ruggedness and open architecture of industrial PCs coupled with the powerful SIMATIC WinAC software PLC. A SIMATIC S7 is integrated into the industrial PC as a software PLC and the PC-based controller is configured and programmed the same way as other S7 controllers. All the automation components are integrated into a single industrial PC, resulting in a complete and cost-effective solution.

TIA Portal

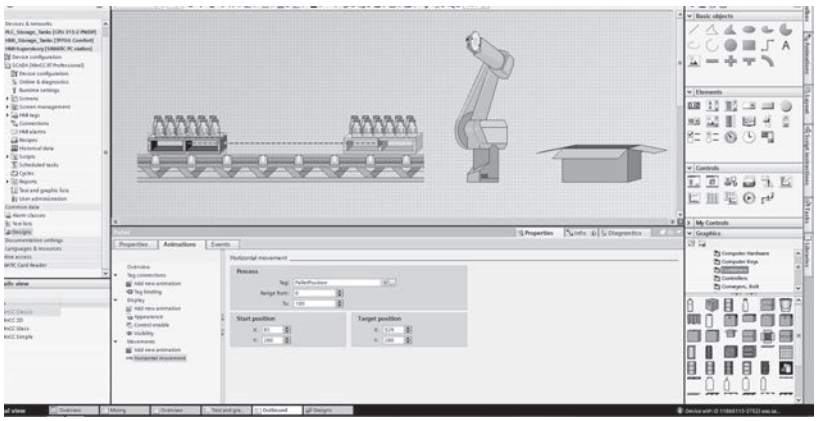
Totally Integrated Automation Portal (TIA Portal) is an innovative engineering framework that unifies multiple automation tools into a single, intuitive development environment, enabling controller programming, HMI screen design, and other automation tasks to be performed using a similar editor design.

Human Machine Interface Software

Just as it is often necessary to use a PLC to coordinate the operation of multiple machines in an assembly process, it is also often necessary to provide a graphical representation of the current status of this process. In addition to providing this graphical representation, an HMI system can provide a custom interface to allow operation personnel to control some or all of the process and for maintenance personnel to obtain system diagnostic information.

SIMATIC WinCC (TIA Portal), SIMATIC WinCC, and **SIMATIC WinCC Open Architecture** product families cover the entire range of engineering and visualization software for the human machine interface (HMI).

SIMATIC WinCC (TIA Portal) is part of an integrated engineering concept which offers a uniform engineering environment for programming and configuration of HMI solutions.



Industrial Networks

In any complex assembly process, the need for rapid information flow is critical. Conditions at any point in the process may impact the entire process. This need for information flow often requires that intelligent devices such as PLCs, intelligent sensors, drives, computers, and HMI systems be interconnected by one or more **local area networks (LANs)**.

A LAN is a communication system designed for private use in a limited area. LANs are used in office areas as well as in manufacturing environments; however, LANs used in industrial applications must be able to operate reliably in conditions that are unsuitable for office-grade equipment. Industrial environments typically have a high level of electrical noise and mechanical vibration and a greater range of temperature and humidity than found in office environments.

Specifications for industrial LANs vary considerably depending upon the requirements of the application. Issues such as the amount of data to be communicated, the rate at which data must be communicated, the number of devices to be connected, the reliability and noise immunity required, compatibility with other networks, and cost are examples of important considerations. In general, it is not possible for one network type to maximize all characteristics. For example, a network that can communicate a large amount of data in a short time is likely to be more expensive than a network that has more limited requirements. Therefore, many factories use a multi-level network structure.

In the past, these networks were often proprietary systems designed to a specific supplier's standards. Siemens is a leader in promoting the trend to open systems based upon international standards developed through industry associations. Siemens **SIMATIC NET** offers an integrated, industry-standard range of industrial network solutions from industrial versions of Ethernet to field device level networks.

Ethernet has become so popular that it is considered the de facto standard for office communications. **Industrial Ethernet** is a high-performance network designed to IEEE 802.3 (Ethernet) and IEEE 802.11 (Wireless LAN) standards. In order to provide the performance and reliability needed for high-speed factory networks, Industrial Ethernet uses industrial-grade switching technology. An **Industrial Ethernet switch** is an active network component that allows multiple devices to communicate simultaneously at high speeds.

The Siemens SIMATIC NET product family includes a range of **SCALANCE X Industrial Ethernet switches** to fit varied requirements from localized to plant-wide networks. Siemens also offers an extensive array of devices for interconnecting network components via twisted-pair cable, optical fiber, or wireless signals. For example, Siemens **FastConnect system** includes cables and connectors designed for demanding factory applications and a cable stripper designed to speed installation.

Like office networks, industrial networks also need to be protected from unauthorized access and from any unnecessary communication load that would affect network performance. **SCALANCE S** modules and security software provide an integrated approach to security tailored to the demands of industrial networks.

Where wireless communication is needed, **SCALANCE W** provides technology for **Industrial Wireless LAN (IWLAN)** communication. IWLAN is based on the IEEE 802.11 standard, but is adapted to the need for reliable communication in noisy industrial environments.

PROFINET is the open Industrial Ethernet standard of PROFIBUS & PROFINET International (PI) and the leading Industrial Ethernet standard world-wide. **PROFINET IO**, the most widely-used form of PROFINET, handles both non-time-critical IT communications and the full range of real-time control communications. By virtue of its ability to handle control tasks, PROFINET extends the benefits of standardized, Ethernet communication to distributed field devices. This approach allows field devices from many suppliers to be easily connected to the network. PROFINET also protects investments in existing PROFIBUS networks by simplifying their integration into a factory-wide network.

PROFIBUS is the open fieldbus standard of PI. A fieldbus is a multi-drop network that provides a standardized approach for communication of devices commonly used for factory automation or process control. The version of PROFIBUS most widely used in factory automation applications is PROFIBUS DP.

The **Actuator-Sensor Interface (AS-Interface)** is an open, low-cost network endorsed by the AS-International Association that simplifies the interconnection of actuators and sensors with controllers. AS-Interface replaces the complex wiring and proprietary interfaces often used for this interconnection with only two wires which transfer both data and power.

IO-Link is an open communication standard developed by the IO-Link research group of the PROFIBUS & PROFINET International organization in response to the need for a simple, low-cost way to allow actuator and sensor communication in a concentrated area, such as for a control panel or individual machine. IO-Link is a point-to-point system, not a fieldbus. It uses a three-wire cable, 24 VDC power supply, and an IO-Link master.

Safety Integrated

Safety has long been an important consideration in factory operation. As Werner von Siemens, the founder of Siemens, stated in 1880, "the prevention of accidents must not be understood as a regulation required by law, but at a precept of human responsibility and economic reason."

Unfortunately, regulations are necessary to both clarify and promote appropriate standards. In addition, these regulations need to be modified periodically to adapt requirements to changes in technology.

In recent years, safety has taken on an even greater importance both as a result of changing regulations and standards and the emergence of new technologies. As a result, Siemens developed the **Safety Integrated** system which includes products which offer comprehensive and consistent safety solutions for production and process industries. Because Safety Integrated has been developed consistent with Siemens **Totally Integrated Automation (TIA)**, both standard and safety-related components are combined in one uniform system. This results in considerable cost savings for our customers.

Included in the extensive array of Safety Integrated products are fail-safe SIMATIC PLC Central Processing Units (CPUs), fail-safe SIMATIC ET 200 Input/Output (I/O) devices and systems, SIRIUS Safety Integrated industrial controls, and fail-safe drives and motion control systems.

Because Safety Integrated uses proven PROFINET, PROFIBUS, and AS-Interface networks for fail-safe communication, engineering and installation costs are significantly reduced. Where needed, **PROFIsafe** and **ASIsafe** can be used. PROFIsafe is an open solution for safety-oriented communication that uses PROFINET and PROFIBUS services. ASIsafe is the safety version of the AS-Interface system.

SIMATIC IT Manufacturing Execution System

There are a variety of manufacturing information technology (IT) systems. For example, manufacturing facilities have long used Enterprise Resource Planning (ERP) systems to manage the flow of materials associated with manufacturing processes. In recent years, many companies have also been using a **Manufacturing Execution System (MES)**. While the function and definition of an MES varies depending upon the supplier and the specific software suite purchased, an MES is designed to provide timely production information that enables manufacturing personnel to improve operational efficiency and reduce costs.

Siemens **SIMATIC IT** is a set of software suites designed in compliance with the ISA-95 industry standard that operates in harmony with ERP systems. SIMATIC IT reduces the cost to deploy an MES by allowing customers to choose from a set of software bundles to achieve the specific functionality needed.

Review 5

1. Siemens _____ motor control centers have been designed to incorporate a variety of Siemens products that offer optimal motor control, communications, monitoring, protection, and automation interfacing.

2. _____ is a flexible, modular motor management system that provides multifunctional, solid-state protection for constant speed motors.

3. THE SIRIUS 3R modular system of components includes SIRIUS _____ and _____ soft starters for standard applications and _____ soft starters for high feature applications.

4. The SINAMICS _____ variable frequency drive is designed for single phase, 200-240 VAC applications up to 4 HP.

5. For motion control applications, Siemens offers both _____ systems as well as a variety of precision drives, motors, and related products.

6. _____ PLCs are available as conventional modular controllers, embedded automation products, or as PC-based controllers.

Batch and Continuous Processes

Thus far, we have discussed equipment used in discrete parts manufacturing or assembly applications. In addition to these types of manufacturing processes, electrical equipment is also used to manufacture a variety of products using batch or continuous processes.

Batch Processes

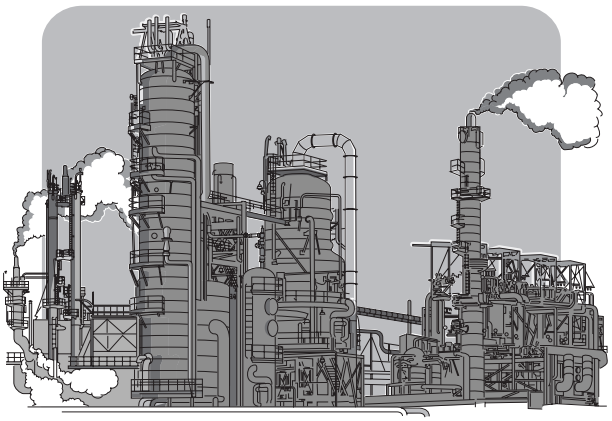
Batch processes are familiar to most people since we use them in everyday life. For instance, when we bake a cake, we follow a recipe that involves adding ingredients, stirring the mixture, pouring it into baking pans, putting the pans into the oven for a specific time at a specific temperature, etc. Industrial batch processes are similar to the process of baking a cake but scaled up to produce a larger quantity of material.

A variety of products are produced using batch processes. Food, beverages, pharmaceutical products, paint, fertilizer, and cement are a few of the categories of products produced using batch processes. Some products such as food, beverages, and pharmaceuticals require precise tracking of batch information for safety and regulatory purposes.

Continuous Processes

Continuous processes are less understood by most people; however, they have some similarities to batch processes. Ingredients must be combined in precise ways at precise points in the process. Precise control of process conditions must be maintained to ensure product quality and safety of operations.

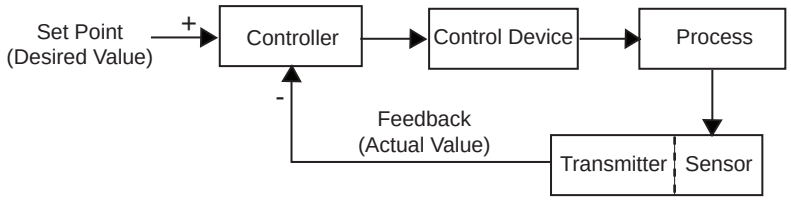
Some industries, such as chemical and petrochemical industries, use continuous processes extensively. Many other industries, however, use continuous processes as some part of their operations for purifying air and water, treating waste products, etc.



Both batch and continuous processes use many of the products discussed thus far. However, there are some unique characteristics of batch and continuous processes that either require the use of additional types of equipment or require some of the equipment previously discussed to be applied differently.

Closed-Loop Control

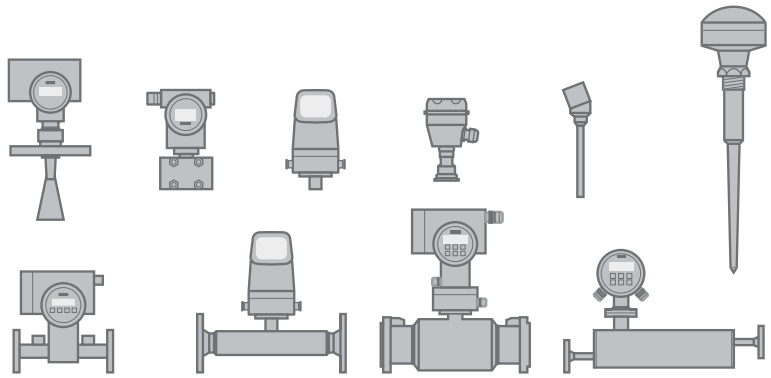
One characteristic of batch and continuous processes is their extensive use of analog data. Analog values can vary continuously within a specified range. The analog data may be representative of temperature, pressure, rate of flow, weight, thickness, viscosity, humidity, or any other characteristic of importance to the process. Both batch and continuous processes require continuous monitoring at numerous points throughout the process. In addition, a corrective action is often required to insure that the process stays within specifications. This type of control that involves measuring a value, comparing the measured value to a desired value or set point, and correcting for the error is called closed-loop control.



Process Instrumentation

Because process types and requirements vary widely, many types of sensors, transmitters, actuators, and other devices are used for process measurement and control. The following product families are examples of the types of process instrumentation products Siemens offers.

- **SITRANS P products** provide a range of instruments for measuring relative, differential, and absolute pressure.
- **SITRANS T products** provide true temperature measurements, even under extreme conditions,
- **SITRANS F products** include electromagnetic, coriolis, ultrasonic, rotary piston, differential pressure, vortex, and variable area flowmeters.
- Siemens process instrumentation products include a variety of point and continuous level measuring instruments.
- **SIPART PS2** are intelligent electropneumatic positioners designed to provide precision valve control.
- Siemens process protection devices can be used to detect situations such as flow problems, blockages, screen fault, cavitation in pumps, or burst filter problems.
- Siemens remote displays and paper and display process recorders offer solutions for process measurement, monitoring, and recording.



Siemens Process Instruments

Process Analytics

Many processes require analytical equipment to determine the composition of materials. Because the nature of the material and the analysis required differs from process to process, Siemens offers a variety of process analyzers and process analysis systems.

Weighing Systems

Siemens offers a comprehensive range of products and systems for weighing and batching technologies. Examples include: weighing electronics, load cells, belt weighing products, and solids flow meters.

Process Visualization

The range of SIMATIC HMI operating and monitoring products includes three software families: **SIMATIC WinCC (TIA Portal), SIMATIC WinCC,** and **SIMATIC WinCC Open Architecture** We have already discussed one of these families, SIMATIC WinCC (TIA Portal).

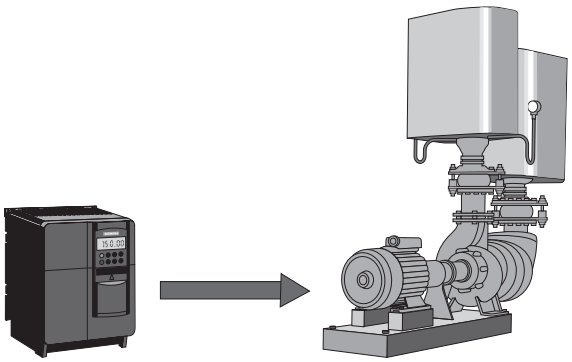
SIMATIC WinCC is a scalable, Windows-based process visualization system, or what is sometimes called a supervisory control and data acquisition (SCADA) system. SIMATIC WinCC is scalable because it can be configured to provide complete operating and monitoring functionality for simple, single-user systems up to complex, multi-user systems with redundant servers.

WinCC Open Architecture addresses solutions with highly customer specific adaptation requirements and specialized functions even on non-Windows platforms.

Process Control

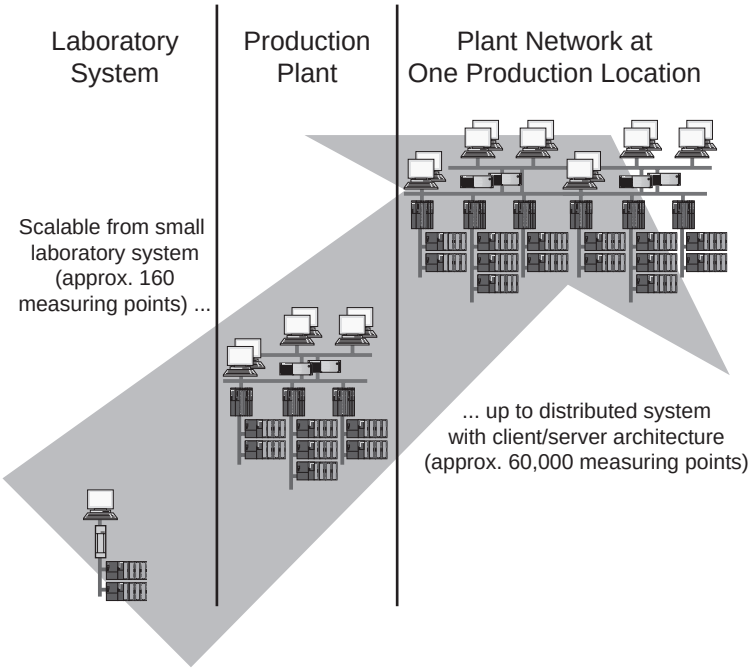
A variety of approaches can be used for process control depending upon the complexity of the process being controlled. A small batch process often lends itself well to control by one PLC or a few networked PLCs.

Increasingly, variable frequency drives (VFDs) are also networked to the PLC and HMI systems. These drives are used to control the speed of pumps or fans that, in turn, control the flow of fluids and gases. Flow control is frequently accomplished by using control valves and vent damping systems to regulate flow while running pump and fan motors at full voltage. Using variable frequency drives for pump and fan control is a more energy efficient approach to controlling process flow rates. Additional efficiencies can be gained through use of more efficient motors and by using smart MCC technologies, such as those available with our tiastar MCCs, to integrate motor management and process control.



Traditionally, medium to large process applications have been controlled by a **distributed control system (DCS)** that is based on proprietary hardware and software that often do not integrate well with other systems.

By comparison, Siemens **SIMATIC PCS 7** uses a more flexible approach. SIMATIC PCS7 uses standard hardware and software from the SIMATIC TIA family. The uniform data management, communication, and configuration capabilities of TIA provide an open platform for solutions in batch, continuous, and hybrid process applications. In addition, the uniform automation technology also facilitates the optimization of all company operations from the ERP level to the field level.


Laboratory System
Production Plant
Plant Network at One Production Location
Scalable from small laboratory system (approx. 160 measuring points) ...
... up to distributed system with client/server architecture (approx. 60,000 measuring points)

All This and Much More

No single book can adequately describe all the products and services Siemens offers. However, you can learn much more about Siemens products and services at this web site: **www.usa.siemens.com**. While you are exploring this site, take note of the additional systems and services that were not discussed in this book**.**

Other STEP Courses

Hopefully, this course, along with our Basics of Electricity course, has provided you with a base of knowledge that will make our other STEP courses more useful and interesting to you. Keep this book handy so that you can use the pictorial glossary to assist you in your additional training or with your daily work.

Review 6

1. _____ control involves measuring a value, comparing the measured value to a desired value, and correcting for the error.

2. _____ products provide a range of instruments for measuring relative, differential, and absolute pressure.

3. _____ is a scalable, Windows-based process visualization system.

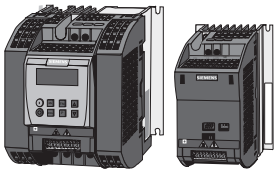
4. _____ is a process control system that uses standard hardware and software from the SIMATIC TIA family.

Pictorial Glossary

The pictorial glossary includes definitions and illustrations for many terms that are frequently used in the electrical industry. Terms that are underlined and italicized are included in the glossary as a separate definition.

AC Drive

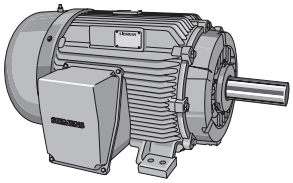
An electronic device used to control the speed of an *AC motor*. Also called a *variable frequency drive* or an *inverter*. The term *variable speed drive* applies to both *AC Drives* and *DC Drives*.



SINAMICS G110 AC Drives

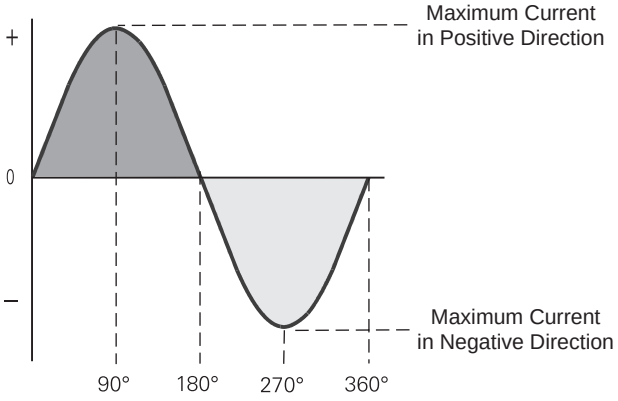
AC Motor

A *motor* that uses *alternating current* to convert electrical energy into mechanical energy. Many AC motors used in industrial applications are three-phase induction motors.



Alternating Current (AC)

Current that periodically reverses direction.



Ambient Temperature

The temperature of the medium (such a air) surrounding a device.

American National Standards Institute (ANSI)

A nongovernmental organization that promotes and coordinates the development of standards and accredits the procedures of other organizations that develop standards.

American Wire Gauge (AWG)

A common method of specifying wire size (cross-sectional area). Larger numbers represent smaller wires. After AWG No. 1, the largest sizes are AWG No. 0, AWG No. 00, AWG No. 000, and AWG 0000. AWG No. 0 is called one-aught, AWG No. 00 is called two-aught, etc.

Ammeter

A meter designed to measure *current*.

Ampacity

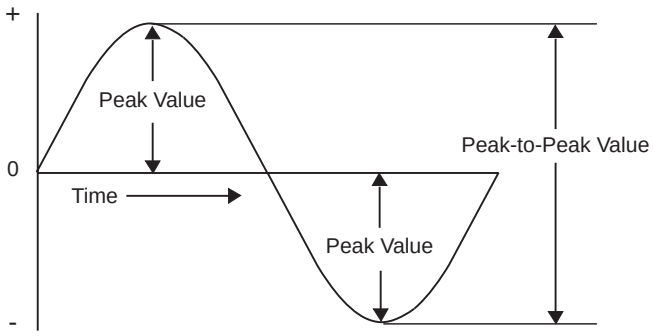
The continuous *current* rating in *amperes* for a conductor.

Ampere, Amp

The basic unit for *current*. An ampere, also called an amp, is equal to a current of 1 *Coulomb* per second. The symbol for ampere is "A."

Amplitude

The total variation of a waveform. Amplitude can be expressed as a peak value, peak-to-peak value, or *effective value*.

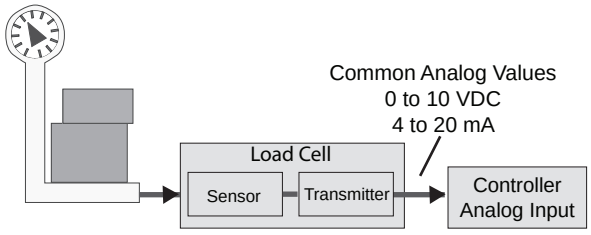


Analog

A value that is continuously variable. Also used to describe circuits that work with analog signals.

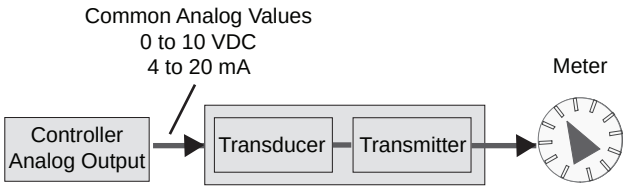
Analog Input

An input to a system that can continuously vary over a range of *current* or *voltage* such as 4 to 20 milliamps or 0 to 10 volts.



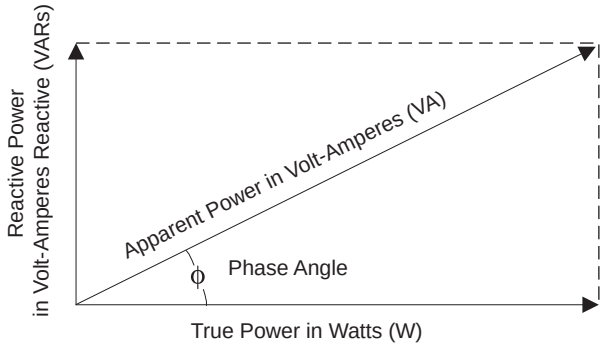
Analog Output

An output from a system that can continuously vary over a range of *current* or *voltage* such as 4 to 20 milliamps or 0 to 10 volts.



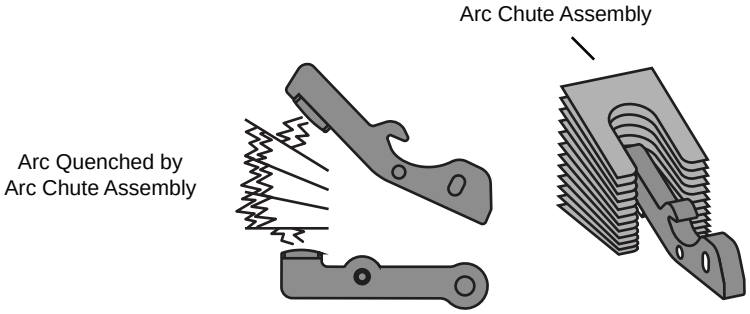
Apparent Power

The vector sum of *true power* and *reactive power*. Apparent power is calculated by multiplying *current* times *voltage*. The unit for apparent power is the volt-ampere, abbreviated "VA."



Arc Chute Assembly

An assembly of metal plates surrounding *circuit breaker* or *contactor* contacts. Arc chutes are used to reduce contact damage by quickly extinguishing the arc created when contacts open.



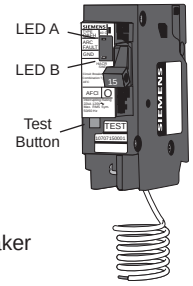
Arc Fault

An electrical arc which results when *current* flows in unintended ways, but in residential applications, often not in sufficient amounts to cause a standard circuit breaker to trip. Residential arc faults typically result from worn or damaged insulation and are a common cause of fires. In larger applications, an arc fault can cause an *arc flash*.

Arc Fault Circuit Interrupter (AFCI)

A *circuit breaker* designed to provide protection from the effects of an *arc fault* by recognizing the characteristics unique to arcing and de-energizing the circuit when an arc fault is detected. The most effective AFCI circuit breakers are combination AFCIs which provide protection against all three known types of arc faults.

LED Indicator		Last Known Trip Condition
LED (A)	LED (B)	
OFF	OFF	Overcurrent
ON	OFF	Arc Fault
ON	ON	Arc Fault to Ground



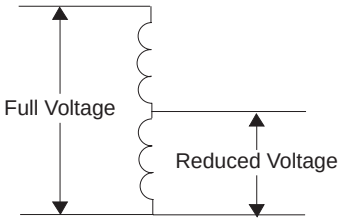
Siemens Combination AFCI Circuit Breaker

Arc Flash

A condition that occurs as a result of a high energy *arc fault* where heat energy is suddenly, and often explosively, produced.

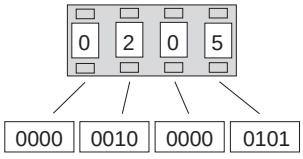
Autotransformer

A type of *transformer* in which the secondary coil is part of the primary coil. Often the secondary *voltage* is adjustable via a movable tap.



Binary-Coded Decimal (BCD)

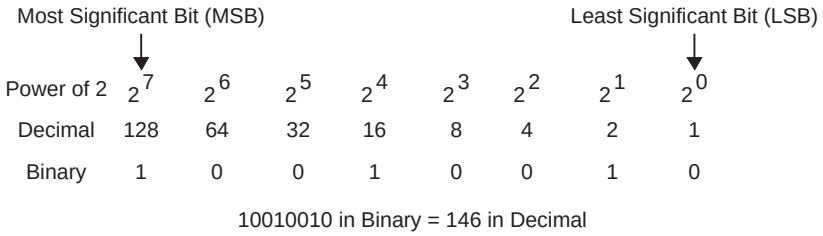
Usually refers to the 8-4-2-1 code where four *bits* are used to represent decimal digits 0 through 9.



Decimal	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Binary Number

A number made up only of 1's and 0's that represent powers of two (2). *Digital* equipment uses binary numbers to represent numerical values and the on or off condition of devices.


Most Significant Bit (MSB)
Least Significant Bit (LSB)
Power of 2 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0
Decimal 128 64 32 16 8 4 2 1
Binary 1 0 0 1 0 0 1 0

10010010 in Binary = 146 in Decimal

Bit

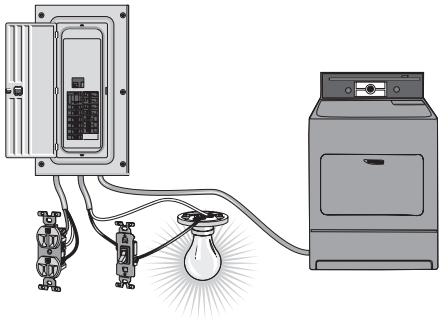
A 1 or 0 representing one position in a *binary* number.

Bonding

The permanent joining of metal parts to form an electrically conductive path.

Branch Circuit

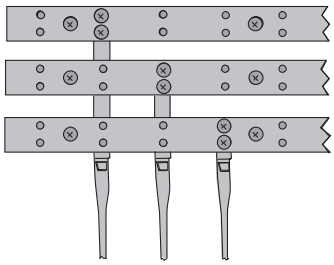
A part of a *power* distribution system extending beyond the final *overcurrent* protection device.



Branch Circuits

Bus

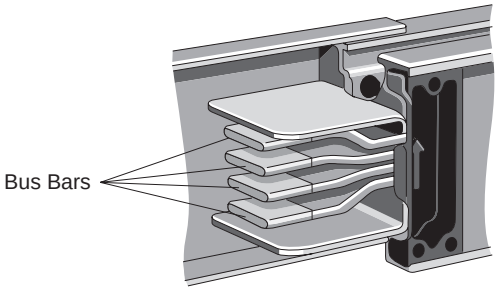
A group of *conductors* used to supply *power*, data, or control signals.



Vertical Bus

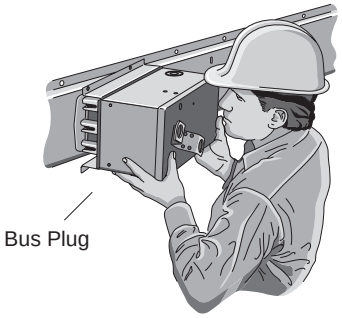
Bus Bar

A *conductor* that serves as a common connection for two or more circuits.



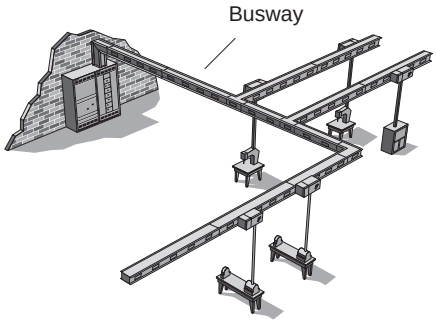
Bus Plug

A device used with *plug-in busway* to provide *power* connections close to the intended load.



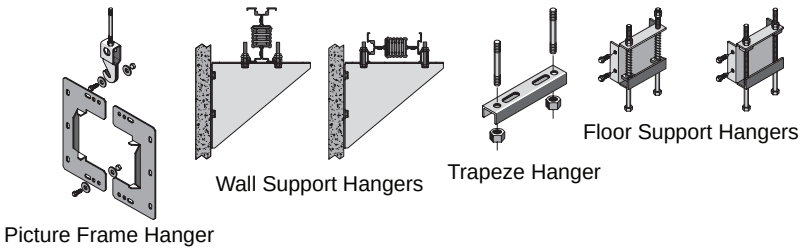
Busway

A prefabricated electrical distribution system that uses *bus bars* in a protective *enclosure*.



Busway Hangers

Devices used to suspend *busway* from a ceiling or mount it to a wall.



Byte

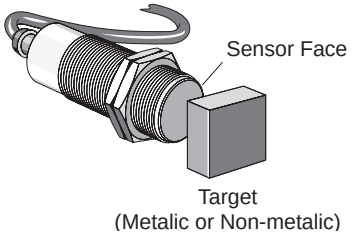
Eight consecutive *bits*.

Capacitance

The property of a circuit or device that allows it to store an electrical charge. The symbol for capacitance is "C." The unit for capacitance is the *farad*.

Capacitive Proximity Switch

A type of *sensing switch* that produces an electrostatic field to detect the presence of an object without touching the object.



Capacitive Reactance

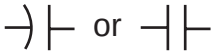
The opposition to *alternating current* resulting from circuit *capacitance*. Capacitive reactance is inversely proportional to *frequency* (f) and capacitance (C). The symbol for capacitive reactance is "X_C." The unit for capacitive reactance is the *ohm*.

$$X_C = \frac{1}{2\pi fc}$$

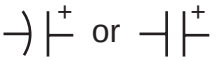
Capacitor

A device manufactured to have a specific *capacitance*.

Capacitor (Non-Polarized)



Capacitor (Polarized)

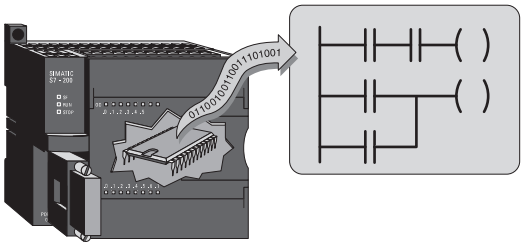


$$C = k\frac{A}{d}$$

A – Area of the plates
d – Distance between plates
Dielectric constant

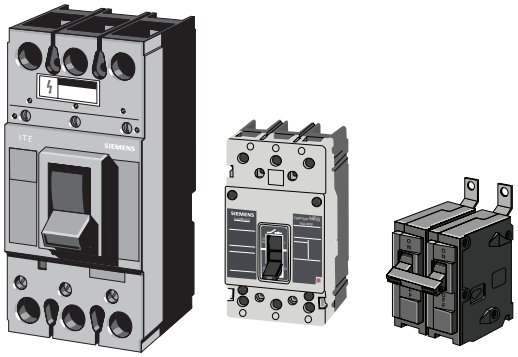
Central Processor Unit (CPU)

The decision-making part of a computer. May also be used to describe the processing circuits together with memory and other circuits needed for processing information.



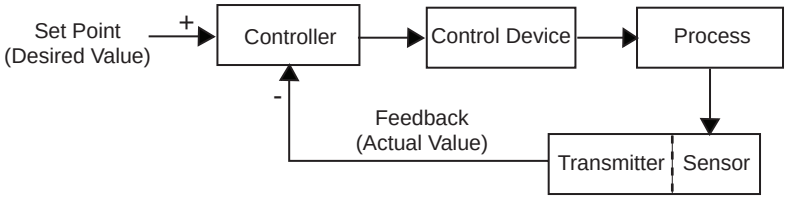
Circuit Breaker

A device that can be used to open or close a circuit manually and also opens a circuit automatically when it senses an *overcurrent*.



Closed-Loop Control

A control technique that compares a *feedback* signal representative of an actual value with a desired value and responds to minimize the error.

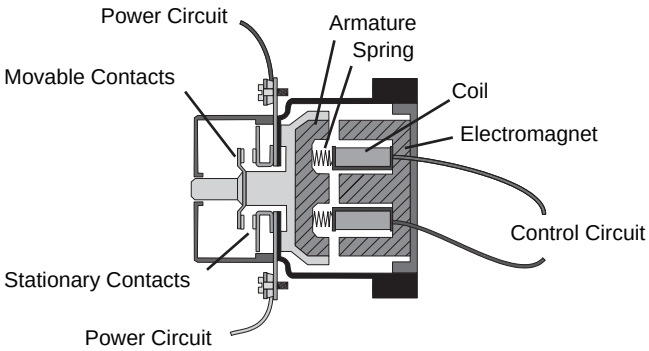


Conductor

A material that permits electrons to easily move through it. Copper, silver, and aluminum are examples of materials that are good conductors. Also used generically to refer to a wire, cable, or *bus bar* that is made from a conducting material.

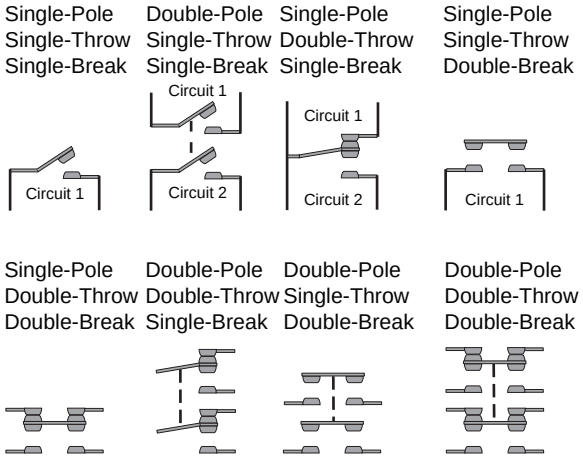
Contactor

Often refers to a device with large contacts that close when current is applied to its electromagnet; however, solid state contactors are also available. Contactors are used to control the power applied to motors, lights, or heating components.



Control Relay

Often refers to a device with contacts that open and close electromagnetically, but solid state control relays are also available. Control relays typically handle smaller currents than contactors, but are capable of switching more rapidly.



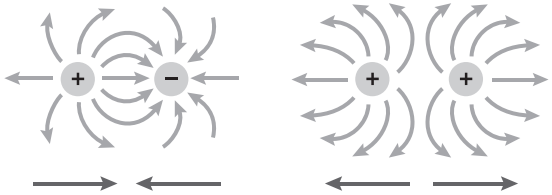
Control Relay Contact Types

Coulomb

A unit of electrical charge moved in 1 second by a current of 1 ampere. This is equal to approximately 6.24 x 10^{18} electrons.

Coulomb's Law

A law that states that charged objects attract or repel each other with a force that is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.



Unlike Charges Attract Like Charges Repel

Counter EMF

A *voltage* created in an inductive circuit that opposes a change in *current* flow. EMF stands for electromotive force.

Current

The flow of electrons in a circuit. Current is designated by the symbol "I" and is measured in *amperes*.

DC Drive

An electronic device used to control the speed of a *DC motor*. The term *variable speed drive* applies to both *DC Drives* and *AC Drives*.

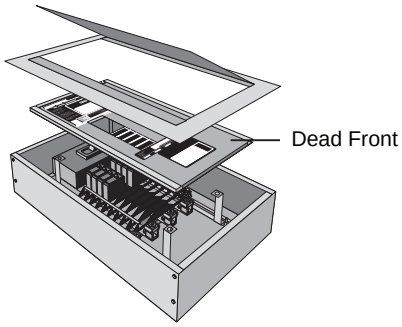
SINAMICS DC Master Drives

DC Motor

A *motor* that converts *direct current* electrical energy into mechanical energy.

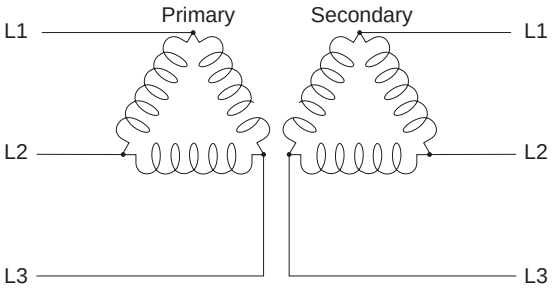
Dead Front

A front portion of a *panelboard* or *switchboard* that limits exposure to electrical connections.



Delta

A connection arrangement used for the primary and/or secondary of a three-phase *transformer*.



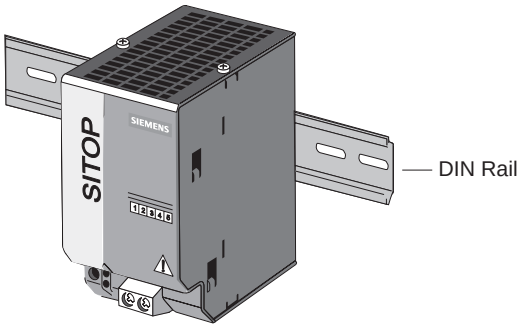
Delta-Delta (△-△)Transformer Configuration

Digital

Used to describe circuits that use on or off (binary) signals. Also used to describe equipment that includes these circuits.

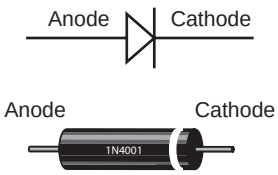
DIN Rail

A mounting bracket manufactured to *German Institute for Standardization (DIN)* specifications. Typically used to mount devices such as small *PLCs*, *motor starters*, *control relays*, power supplies, and other components that are DIN rail compatible.



Diode

A component with two terminals (anode and cathode) that passes *current* primarily in one direction. Often used as part of a *rectifier* circuit.



Direct Current (DC)

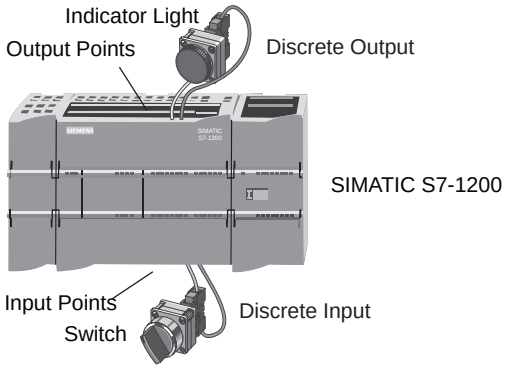
Current with a constant direction.

Disconnect Switch

A switch designed to disconnect electrical *power* from a circuit.

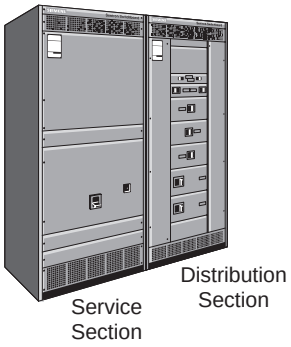
Discrete I/O

Inputs (I) and outputs (O) that are either on or off.



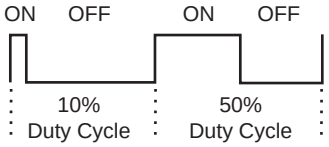
Distribution Section

A *switchgear*, *switchboard* , or power *panelboard* section that receives *power* from the *service section* and distributes power to other circuits.



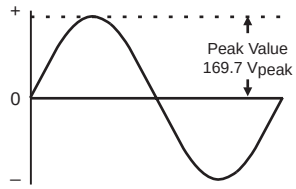
Duty Cycle

The ratio of a device's on time to its total cycle time. Duty cycle is normally expressed as a percentage; therefore, a device with a 50% duty cycle is on half the time.



Effective Value

A measure of the *amplitude* of *alternating current* or *voltage*. Also called the *root-mean-square* or RMS value. Test meters used to measure alternating current or voltage usually display effective values.



169.7 V_{peak} x 0.707 = 120 V_{eff} (also expressed as VAC or Vrms)

Electrically Erasable Programmable Read Only Memory (EEPROM)

A type of *semiconductor* memory often used for storage of data or programs that change less frequently than *random access memory*. The contents of EEPROM chips are erased with electrical pulses rather than with ultraviolet light as with *erasable programmable read only memory*. EEPROMs retain their contents when power is turned off.

Enclosure

A protective housing. Guidelines for various types of electrical enclosures are provided by the *National Electrical Manufacturers Association (NEMA) and the International Electrotechnical Commission (IEC)*.

Encoder

Often refers to a *digital* device that provides angular position information. Some encoders provide this information as incremental pulses as position changes. Other types of encoders provide a digital signal representative of absolute position.

Erasable Programmable Read Only Memory (EPROM)

A type of *semiconductor* memory often used for storage of data or programs that change infrequently, if at all. EPROMs must be removed from the circuit to be erased and reprogrammed. EPROMs retain their contents when power is turned off.

Explosion Proof (XP)

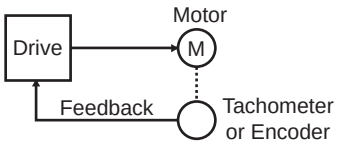
A *motor enclosure* type used in hazardous locations. Explosion proof enclosures are also available for other types of equipment.

Farad

The basic unit of *capacitance*. The symbol for the farad is "F."

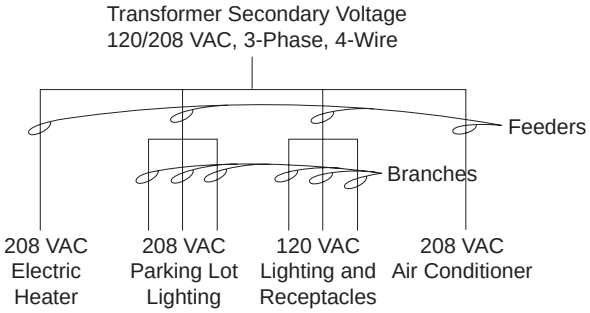
Feedback

A signal provided to a control circuit that is representative of an actual condition in a machine or process.



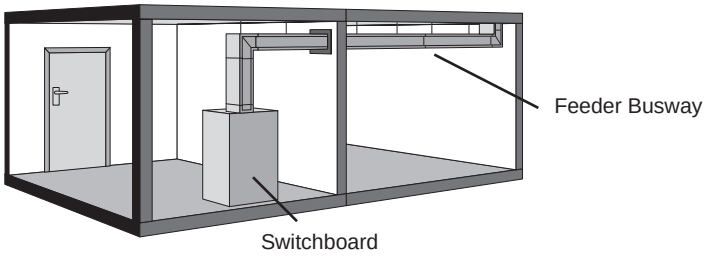
Feeder

Often refers to a set of *conductors* that originates at a main distribution center and supplies *power* to one or more secondary or branch distribution centers.



Feeder Busway

Busway used to distribute *feeder* current to loads that are sometimes remote from the power source.

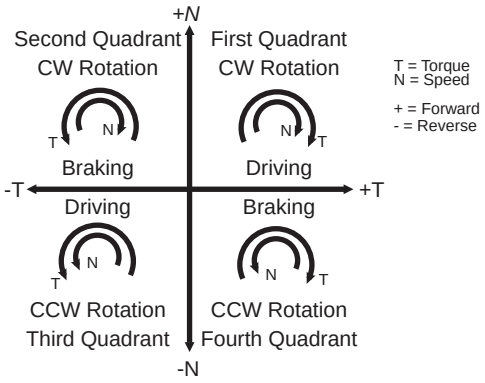


Filler Plates

Plates used to cover unused spaces in a panel.

Four-Quadrant Operation

Describes the operation of a *variable speed drive* that is capable of providing forward or reverse *torque* with the motor rotating in either the forward or reverse direction.

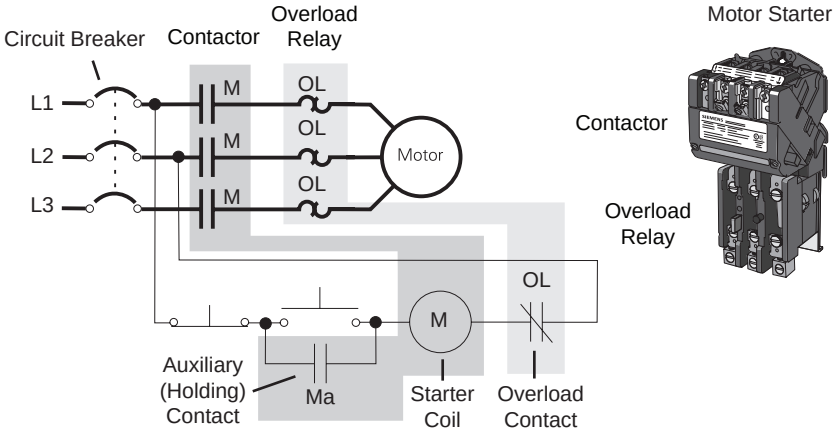


Frequency

The rate of variation of a periodic waveform. The symbol for frequency is "f." The unit for frequency is *Hertz*.

Full-Voltage Starter

A type of *motor starter* often used for three-phase induction motors that applies the full line *voltage* to the motor immediately. Sometimes called an across-the-line starter.



Fuse

A device designed to open a circuit when its rated *current* is exceeded. This is usually accomplished when a metal link in the fuse melts. Renewable fuses allow the user to replace the link and non-renewable fuses do not. Fuses are available in various sizes and types. Some have a time delay.

Fuse Class

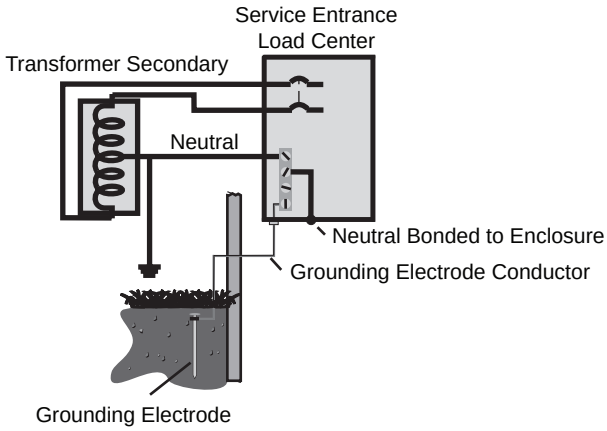
A letter designation given to a *fuse* to identify its operating and construction characteristics.

German Institute for Standardization (DIN)

Recognized since 1975 as the standards organization that represents German interests nationally and internationally.

Ground

A connection to the earth or to a conductive object such as an equipment chassis.

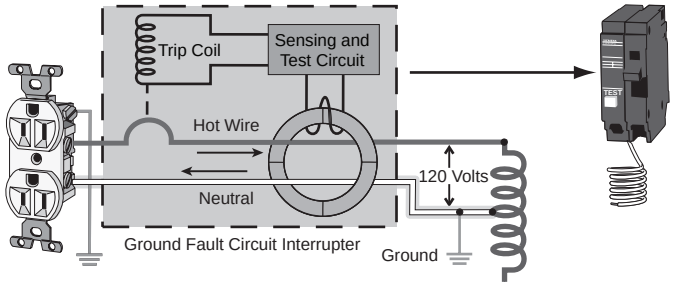


Ground Fault

A condition in which *current* takes an unintentional path to *ground*. Ground faults can endanger people and damage equipment. For this reason, some circuits are equipped with a *ground fault circuit interrupter (GFCI)*.

Ground Fault Circuit Interrupter (GFCI)

A device designed to interrupt *current* in a circuit if a *ground fault* is sensed. If a GFCI is installed near the receptacles it protects, overcurrent protection is required separately. A GFCI circuit breaker combines protection for ground faults, overloads, and short circuits in one device.

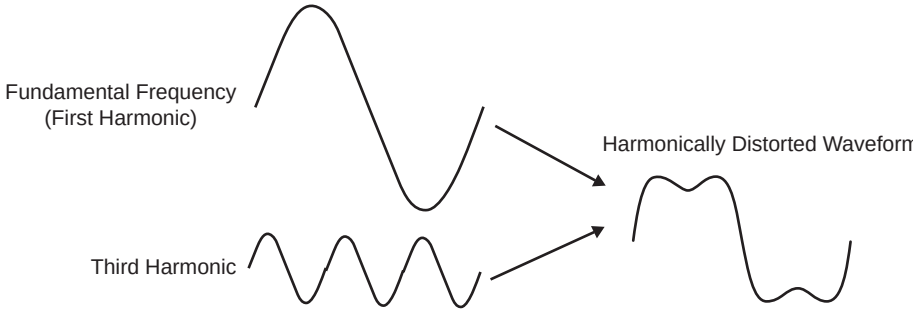


Harmonics

The base *frequency* produced by a circuit is said to be the fundamental *frequency* or first harmonic. Additional harmonics are multiples of the first harmonic. The 3rd harmonic of a 60 Hz power supply, for example, is 3 x 60 Hz = 180 Hz.

Harmonic Distortion

The effect of *harmonics* on the fundamental *frequency*. Harmonic distortion can interfere with the operation of electronic devices.



Henry

The basic unit of *inductance*. The symbol for the henry is "H."

Hertz

A unit of *frequency* equal to one cycle per second. Hertz is abbreviated Hz.

Hexadecimal

A number system that uses powers of 16.

Decimal	Binary	BCD	Hexadecimal
0	0	0000	0
1	1	0001	1
2	10	0010	2
3	11	0011	3
4	100	0100	4
5	101	0101	5
6	110	0110	6
7	111	0111	7
8	1000	1000	8
9	1001	1001	9
10	1010	0001 0000	A
11	1011	0001 0001	B
12	1100	0001 0010	C
13	1101	0001 0011	D
14	1110	0001 0100	E
15	1111	0001 0101	F
16	10000	0001 0110	10
17	10001	0001 0111	11
18	10010	0001 1000	12
19	10011	0001 1001	13
20	10100	0010 0000	14

Horsepower

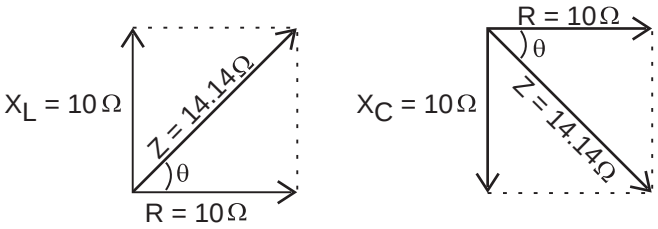
A unit of *power*. Horsepower is abbreviated "HP." 1 horsepower is equal to 746 *watts*.

IEEE

An organization open to individual membership that provides a variety of services for its members, but also develops numerous standards for technology and practices. The organization is now officially known as IEEE (pronounced eye-triple-e) and no longer refers to itself as the Institute of Electrical and Electronic Engineers.

Impedance

The total opposition to *alternating current*. Impedance is the vector sum of *resistance* and *reactance*. The symbol for impedance is "Z." The unit for impedance is the *ohm*.

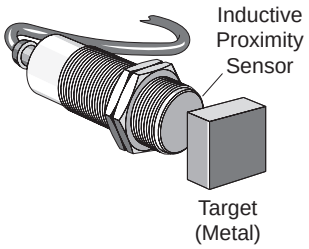


Inductance

The property of an electrical circuit that opposes changes in current. Inductance is designated by the symbol "L" and is measured in *henries*.

Inductive Proximity Switch

A type of *sensing switch* that uses an electromagnetic coil to detect the presence of a metal object without coming into physical contact with it.



Inductive Reactance

The opposition to *alternating current* resulting from circuit *inductance*. Inductive reactance is directly proportional to *frequency* (f) and inductance (l). The symbol for inductive reactance is "X_L" The unit for inductive reactance is the *ohm*.

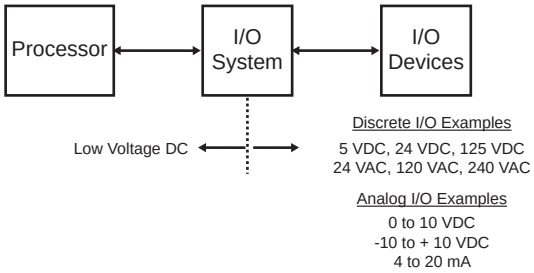
$X_L = 2\pi fl$

Inductor

A device manufactured to have a specific *inductance*. An inductor is often made from a coil of wire and is sometimes called a coil or choke.

Input/Output (I/O) System

The part of a control system that interfaces to the real world. The I/O system accepts signals from switches and sensors, and provides signals to actuating and display devices.



Instrument Transformer

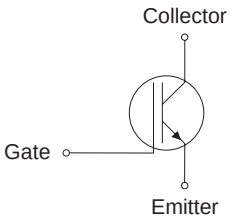
A type of *transformer* used to sense the *voltage* or *current* of associated *conductors* and provide proportional electrical energy to measurement devices or circuits. A potential transformer (PT) is used for voltage measurements and a current transformer (CT) is used for current measurements.

Insulated Case Circuit Breaker

A type of *circuit breaker* that conforms to NEMA AB-1 and UL 489 standards for *molded case circuit breakers* and is often used as a main breaker in switchboards, motor control centers, or in other applications requiring a molded case circuit breaker with a high continuous current rating.

Insulated Gate Bipolar Transistor (IGBT)

A type of *transistor* often used as a switching device in the *inverter* section of a *variable frequency drive*. *Voltage* on the gate element is used to control the *current* flowing between the collector and emitter.



Insulator

A material with a high *resistance* to the flow of electrons. Plastic, rubber, glass, and mica are examples of materials that are good insulators.

International Electrotechnical Commission (IEC)

An organization based in Geneva, Switzerland with over 50 national committees as full members. ANSI represents the U. S. IEC writes international standards for electrical and electronic technologies and practices.

International Organization for Standardization (ISO)

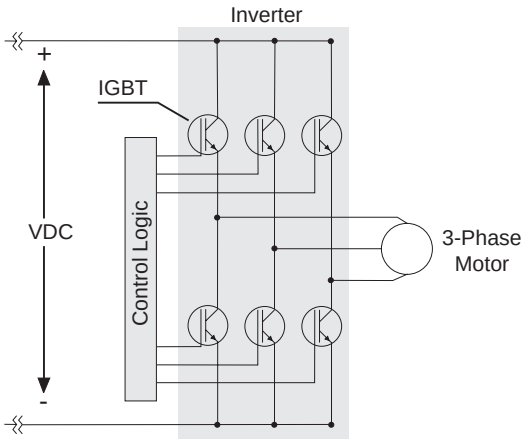
A network of standards organizations from over 150 countries that develops voluntary standards for business, science, and technology. The name ISO is from the Greek word "isos," which means equal.

Interrupting Rating

The maximum level of fault *current* that a *circuit breaker* or *fuse* can safely interrupt at a specific voltage. The interrupting rating is also called the ampere interrupting rating.

Inverter

A device that converts *direct current* to *alternating current*. Inverter is also sometimes used as a synonym for an *AC drive* even though an AC drive usually includes other circuits.



Isolation Transformer

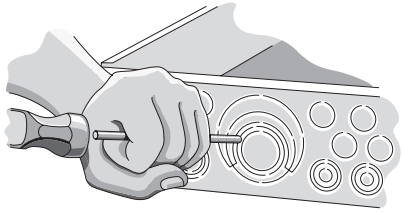
A *transformer* used to limit the transfer of electrical noise from one circuit to another.

Joule

The basic unit of electrical energy. 1 Joule is equal to 1 watt-second or the amount of energy transferred in one second when the *power* is one *watt*.

Knockout

A place in an *enclosure* where a piece of the enclosure can be easily removed to allow for cable entry.

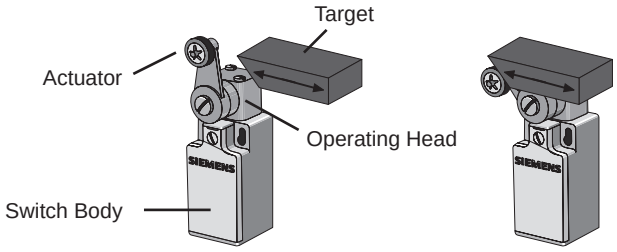


Ladder Logic

A method of programming a *programmable logic controller* that uses symbols that evolved from the diagrams used with *control relays*.

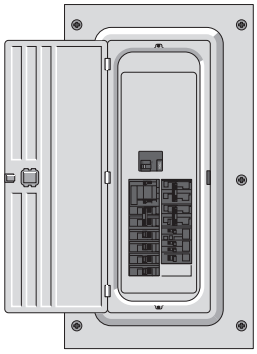
Limit Switch

A type of switch that opens or closes its contacts when its actuator is moved by an object.



Load Center

An industry term used to identify a lighting and appliance *panelboard* designed for use in residential and light commercial applications.

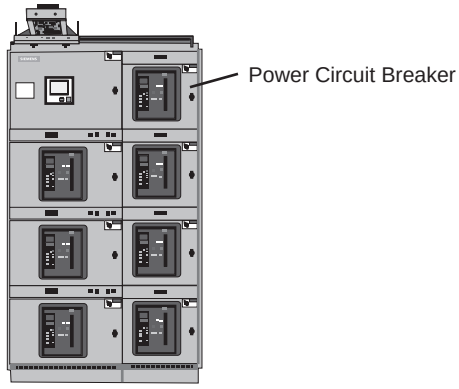


Local Area Network (LAN)

A communication system that interconnects devices within a limited area, but may also connect to other networks for larger-scale communication.

Low Voltage Power Circuit Breaker

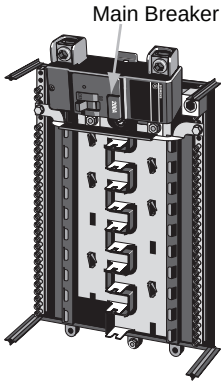
A *circuit breaker,* typically used as a drawout-mounted breaker in low voltage *switchgear,* that conforms to ANSI C37.13, C37.16, C37.17, and C37.50 and UL 1066 standards.



WL Low Voltage Switchgear

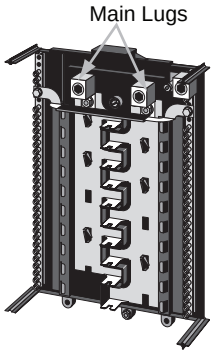
Main Breaker

The *circuit breaker* in or upstream from a *load center*, *panelboard*, *switchboard*, *switchgear* or other equipment that supplies the full current for that equipment.



Main Lug Only

A designation given to indicate that a main breaker or main switch is not included.



MCM

Abbreviation for a thousand circular mils. Circular mills are used to designate the cross-sectional area of a round *conductor*. One mill is equal to 1/1000 of an inch. The circular mill area of a solid, round conductor is calculated by squaring the conductor's diameter (in mills). 1 MCM is 1000 circular mils (also shown as 1 kcmil).

Metric Unit Prefix

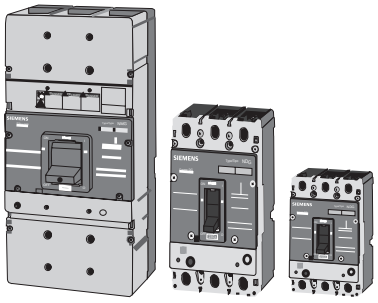
A prefix added to a unit of measure to increase or decrease the size of that unit of measure. For example, the metric unit prefix kilo can be added to meter to form a unit of length (kilometer) equal to 1000 meters. Metric unit prefixes are associated with powers of ten.

Metric Unit Prefix Examples

Value		Prefix	Symbol
1,000,000,000	$= 10^{9}$	giga	G
1,000,000	$= 10^{6}$	mega	M
1,000	$= 10^{3}$	kilo	k
0.001	$= 10^{-3}$	milli	m
0.000001	$= 10^{-6}$	micro	µ
0.000000001	$= 10^{-9}$	nano	n

Molded Case Circuit Breaker

A *circuit breaker* enclosed in an insulated housing. In the United States, molded case circuit breakers conform to NEMA AB-1 and UL 489 specifications.

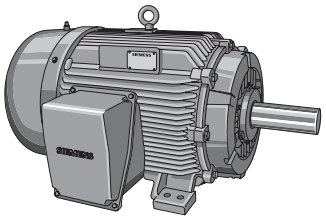


Molded Case Switch

A switch enclosed in the same type of insulated housing as a *molded case circuit breaker*. Siemens molded case switches employ the same operating mechanism as thermal-magnetic and magnetic only circuit breakers. A preset instantaneous function is factory installed to allow the switch to trip and protect itself at a high fault current, but the switch provides no thermal overload protection or short circuit protection.

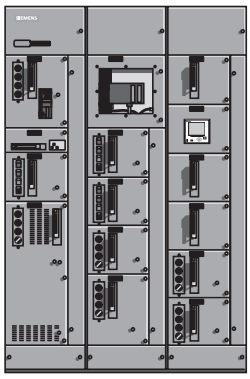
Motor (Electric)

A device that transforms electrical energy into mechanical energy.



Motor Control Center

A metal structure containing multiple *motor* control units. Typically, individual control circuits are mounted in removable containers, often referred to as pans or buckets.



Motor Insulation Class

Standards established by the *National Electrical Manufacturers Association (NEMA)* to meet *motor* temperature requirements found in different operating environments. The combination of an *ambient temperature* of 40°C and allowed temperature rise equals the maximum winding temperature of a *motor*. A margin is also allowed to provide for a point at the center of the *motor*'s windings where the temperature is higher.

Motor Starter

Often refers to a *contactor* and an *overload relay* assembled together to remotely control the operation of a *motor* while providing overload protection. This definition applies to a *full voltage starter*. A variety of other starter types are also available.

Mutual Induction

A process that occurs when varying lines of magnetic flux from one *conductor* induce a *voltage* in an adjacent conductor. This is the basic operating principle of a *transformer*.

National Electrical Manufacturers Association (NEMA)

An organization of manufacturers of electrical equipment that, among other things, develops standards for electrical equipment.

National Electrical Code® (NEC ®)

A document revised every three years based upon inputs to and recommendations of volunteer committee members of the *National Fire Protection Association*. The intent of the *NEC ®*, also called NFPA 70®, is to describe safe electrical practices. Although the *NEC®* is an advisory document, its use is often mandated by state and local building codes.

National Fire Protection Association (NFPA)

A private, nonprofit organization with international membership.
The NFPA has been the sponsor of the *National Electrical Code®* (*NEC®*) since 1911.

NEMA Enclosure Type

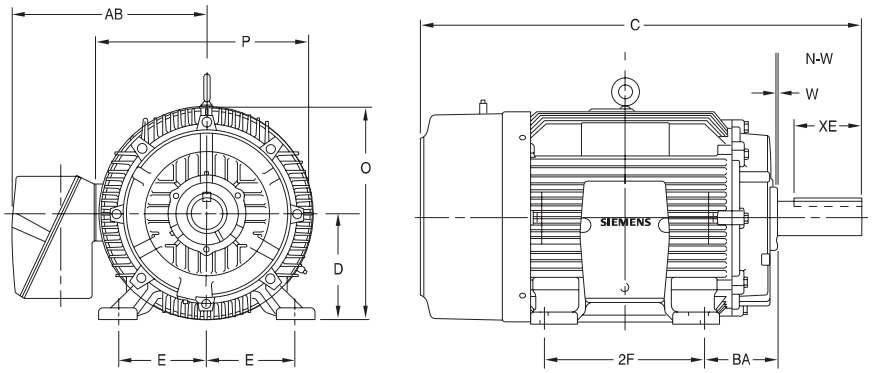
A designation given to an *enclosure* based on standards published by the *National Electrical Manufacturers Association*. The NEMA type identifies the degree of protection provided by the enclosure.

NEMA Enclosure Type Examples

NEMA Type	Description
1	Intended for indoor use. Provides protection against a limited amount of falling dirt.
3R	Intended for outdoor use. Provides protection against rain, sleet, and damage from external ice formation.
4	Intended for indoor or outdoor use. Provides protection against windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.
4X	Intended for indoor and outdoor use. Provides protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.
12	Intended for indoor use. Provides protection against circulating dust, falling dirt, and dripping noncorrosive liquids.

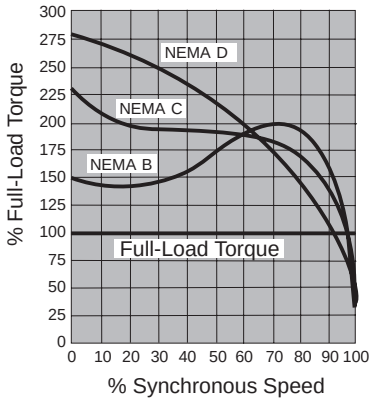
NEMA Frame Size

A designation that identifies motor dimensions based upon standards provided by the *National Electrical Manufacturers Association*. Motors too large to correspond to NEMA frame sizes are referred to as above NEMA motors.



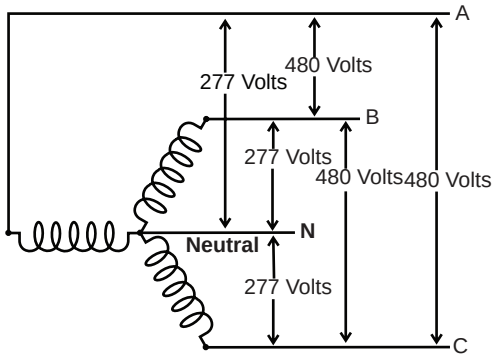
NEMA Motor Design

A letter designation based upon standards established by the *National Electrical Manufacturers Association* that corresponds to a motor's speed and *torque* characteristics.



Neutral

A reference connection in a *power* distribution system.



Ohm

The basic unit of *resistance*, *reactance* and *impedance*. The symbol for the ohm is "Ω", the Greek letter omega.

Ohmmeter

A meter designed to measure *resistance*.

Ohm's Law

A law that states that the *current* in a circuit is directly proportional to the *voltage* and inversely proportional to the *resistance*.

$$I = \frac{E}{R}$$

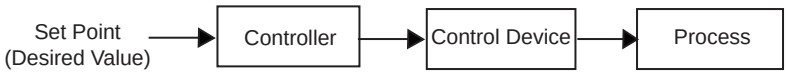
E = Electromotive Force (Voltage) in Volts
I = Current in Amperes (Amps)
R = Resistance in Ohms

Open Drip Proof (ODP)

A motor *enclosure* type that permits air flow through the motor, but is designed to prevent liquids or solids falling from above at angles up to 15 degrees from the vertical from entering the motor.

Open-Loop Control

A control technique that does not use a *feedback* signal.



Overcurrent

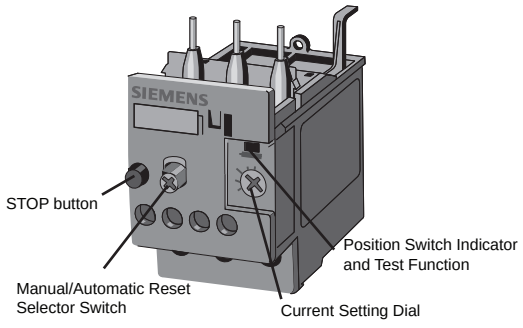
A *current* in excess of the rated current for a device or *conductor*. An overcurrent can result from an *overload*, *short circuit*, or *ground fault*.

Overload

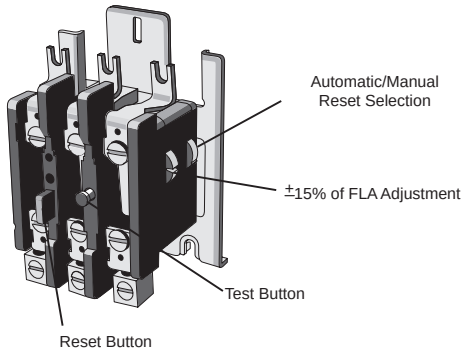
Can refer to an operating condition in excess of the full-load rating or a *current* high enough to cause damage if it is present long enough. *Short circuits* and *ground faults* are not overloads.

Overload Relay

A device used to protect a motor from damage resulting from an *overload.*



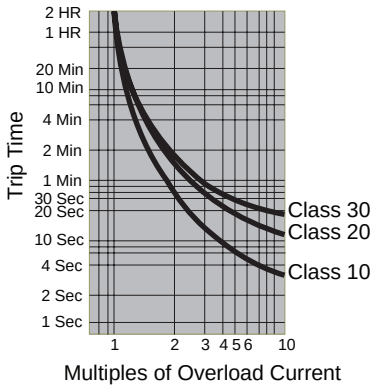
Solid State Overload Relay



Ambient Compensated
Bimetal Overload Relay

Overload Relay Class

Defines the length of time an *overload* condition can exist before an *overload relay* trips. For example, a class 10 overload relay allows 600% of full load amperes for up to 10 seconds.

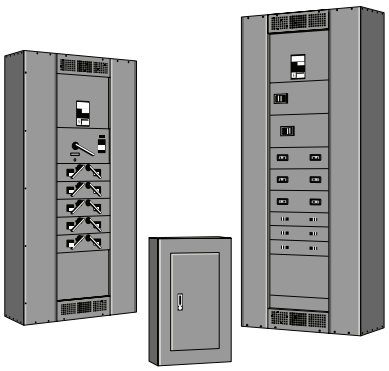


Pad-Mounted Transformer

An enclosed *transformer* mounted on a concrete pad.

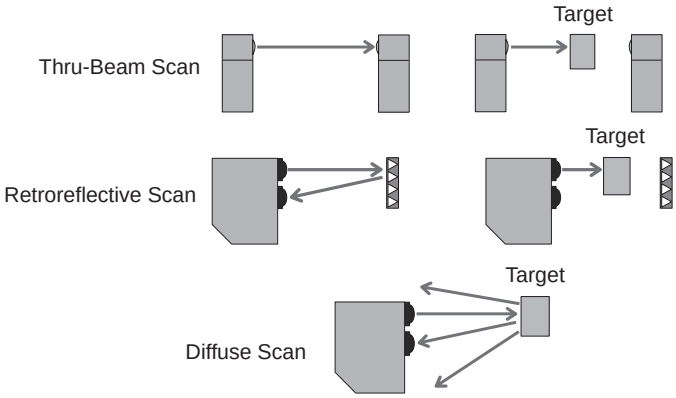
Panelboard

A front-accessible panel containing *overcurrent* protection devices for use in controlling lighting and appliance or *power* circuits.



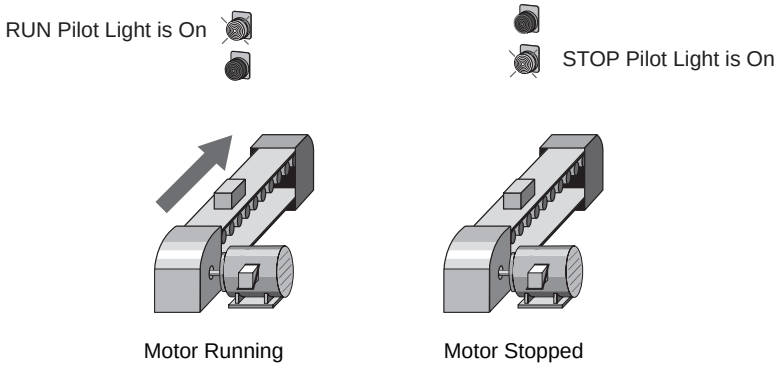
Photoelectric Proximity Switch

A type of *sensing switch* that uses light to detect the presence of an object without coming into physical contact with the object.



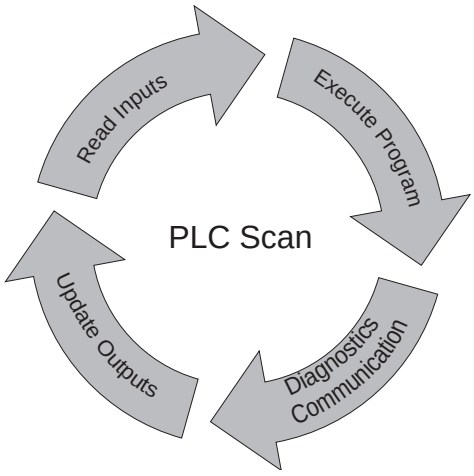
Pilot Light

An indicator light typically used to represent a condition in a machine or process.



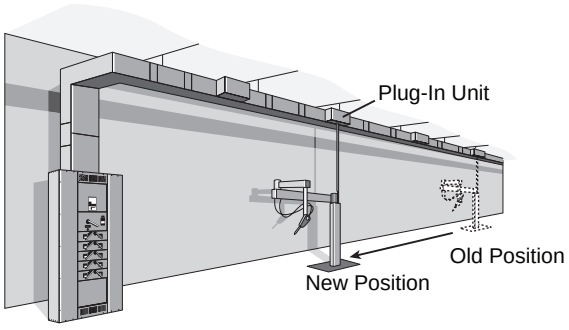
PLC Scan

A complete execution cycle of a *programmable logic controller*. The PLC scan involves updating the status of inputs, executing the user program, performing diagnostic and communication functions, and updating the status of outputs. A PLC scan is repetitively executed.



Plug-in Busway

Busway that incorporates plug-in units, called *bus plugs*, to allow loads to be distributed over the length of the run.



Power

The rate at which work is done or energy is transformed. In an electric circuit, power is measured in *watts,* or sometimes in *horsepower*. The term power is also often used to refer to electrical energy and as an adjective to describe devices or circuits designed to carry a high level of current.

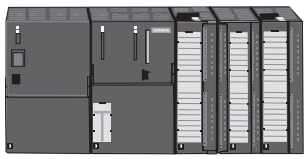
Power Factor

The ratio of *true power* to *apparent power* in a circuit. Power factor is also equal to the cosine of the phase angle.

Programmable Logic Controller (PLC)

A type of industrial computer used to control machines and processes. The PLC accepts inputs from switches and sensors and uses these inputs together with other data and program logic to control output devices.

SIMATIC S7-400



SIMATIC S7-300

Proportional-Integral-Derivative (PID) Control

A *closed-loop control* technique that seeks to minimize error by reacting to three values, one that is proportional to the error, one that is representative of the error over time, and one that is representative of the rate of change of the error.

Proximity Sensor

A type of *sensing switch* that detects the presence or absence of an object without physical contact.

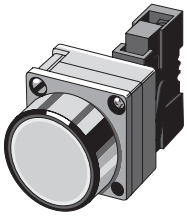
Pulse Width Modulation (PWM)

As applied to *variable frequency drives*, this is a technique for controlling the *voltage* applied to an AC motor by varying the pulse width while also controlling the frequency of the pulses.

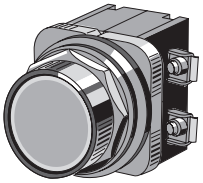
Pushbutton

A control device used to manually open and close a set of contacts.

16 mm 3SB2 Pushbutton



22 mm SIGNUM 3SB3 Pushbutton



30 mm Class 52 Pushbutton

Random Access Memory (RAM)

Usually refers to a type of *semiconductor* memory often used for temporary storage. RAM requires the continual application of *power* to retain information. For some systems, battery backup is used to prevent data or program loss in the event of a power outage.

Reactance

The opposition to *alternating current* resulting from circuit *inductance* and *capacitance*. The symbol for reactance is "X." The unit for reactance is the *ohm*.

Reactive Power

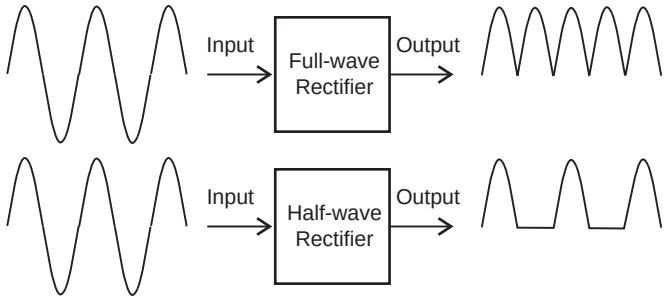
Power associated with *inductance* or *capacitance*. The unit for reactive power is the *var*.

Read Only Memory (ROM)

Usually refers to a type of *semiconductor* memory often used for permanent storage of data or programs that do not change.

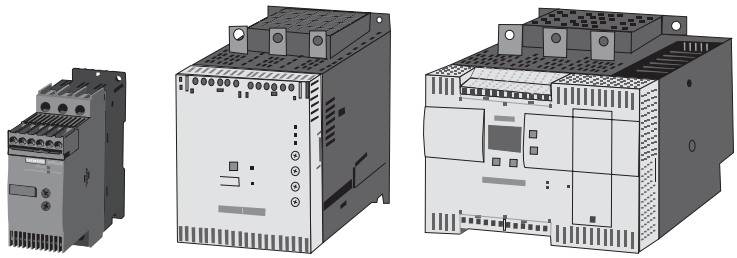
Rectifier

A device or circuit that converts *alternating current* to *direct current*.



Reduced-Voltage Starter

A type of *motor starter* that applies less than the full-line *voltage* to a three-phase induction motor while it is starting. There are a variety of reduced-voltage starters. Some types use electromechanical components and others use electronic components. Electronic reduced voltage starters are often referred to as *solid-state* reduced voltage starters or soft starters.



Resistance

A property of a material or circuit that opposes *current* flow. Resistance is symbolized by "R" and is measured in *ohms*.

Resistance Temperature Detector (RTD)

A device used to sense temperature that varies in *resistance* as temperature changes.

Resistor

A device manufactured to have a specific amount of *resistance* or to be variable within a specific range of resistance. A rheostat is a type of two-lead variable resistor and a potentiometer is a type of three-lead variable resistor.

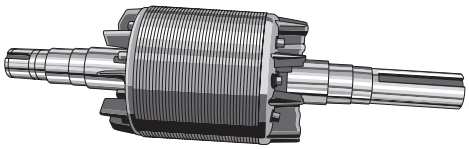
Fixed Value Resistor Rheostat Potentiometer

Root-mean-square or RMS Value

The *effective value* of a *current* or *voltage*. Root-mean-square is descriptive of the mathematical process used to calculate the effective value of a periodic current or voltage.

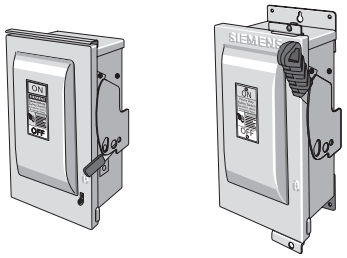
Rotor

The rotating element in the magnetic circuit of a rotating machine such as a *motor*.



Safety Switch

A type of enclosed switch that may also include provisions for fuses. Single-throw safety switches are used to provide a means for disconnecting power. Double-throw switches are used to transfer loads from one power source to another or to transfer power from one load to another.

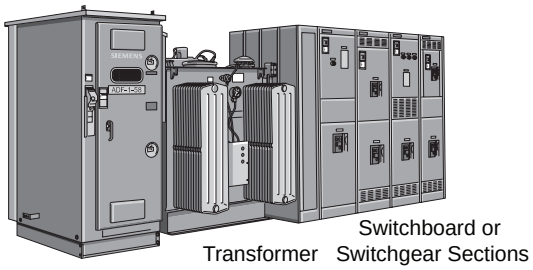


General Duty Heavy Duty

VBII Safety Switiches

Secondary Unit Substation

A coordinated design consisting of one or more *transformers* mechanically and electrically linked to *switchgear* or *switchboard* assemblies with an outgoing *voltage* rated below 1000 *volts*.

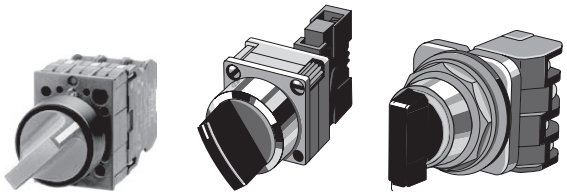


Selective Coordination

Applying *circuit breakers* in a manner that minimizes the extent of an outage in the event of a fault. Circuit breakers are typically installed in a branching arrangement. In the event of a fault, the breaker electrically closest to the fault should trip first. This can be accomplished by properly sizing and adjusting all breakers.

Selector Switch

A manual switch with multiple contact positions.



Semiconductor

A type of material, such as silicon, with more *resistance* than a *conductor*, but less than that of an *insulator*. Semiconductors can be manufactured to produce devices such as *diodes, transistors, thyristors*, etc.

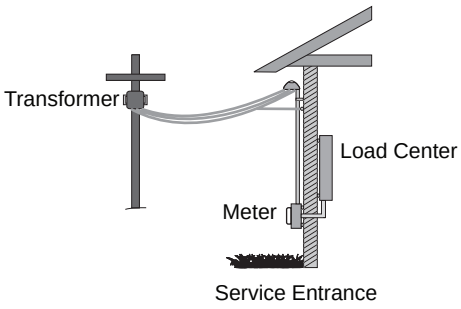
Sensing Switch

A device, sometimes called a sensor, that turns on or off to indicate presence or absence of an object or material. Examples include *limit switches* and *photoelectric* , *inductive*, *capacitive*, and *sonar proximity switches*.

Sensor	Advantages	Disadvantages	Applications
Limit Switch	• High Current Capability • Low Cost • Familiar "Low-Tech" Sensing	• Requires Physical Contact with Target • Very Slow Response • Contact Bounce	• Interlocking • Basic End-of-Travel Sensing
Photoelectric	• Senses all Kinds of Materials • Long Life • Largest Sensing Range • Very Fast Response Time	• Lens Subject to Contamination • Sensing Range Affected by Color and Reflectivity of Target	• Packaging • Material Handling • Parts Detection
Inductive	• Resistant to Harsh Environments • Very Predictable • Long Life • Easy to Install	• Distance Limitations	• Industrial and Machines • Machine Tool • Senses Metal-Only Targets
Capacitive	• Detects Through Some Containers • Can Detect Non-Metallic Targets	• Very Sensitive to Extreme Environmental Changes	• Level Sensing
Ultrasonic	• Senses all Materials	• Resolution • Repeatability • Sensitive to Temperature Changes	• Anti-Collision • Doors • Web Brake • Level Control

Service Entrance

The place where *power* cables enter a building.

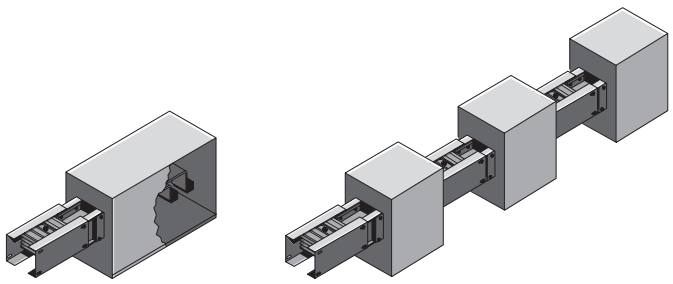


Service Factor

A numerical value that is multiplied by a motor's rated *horsepower* to determine the maximum horsepower at which the motor should be operated.

Service Head

A device used to connect *busway* at the *service entrance*.



3-Phase Service Head

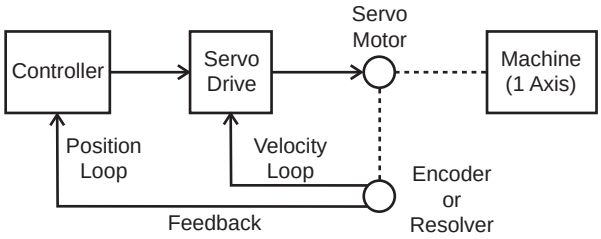
Three 1-Phase Service Head

Service Section

The switchgear, *switchboard*, or power *panelboard* section connected to incoming *power*.

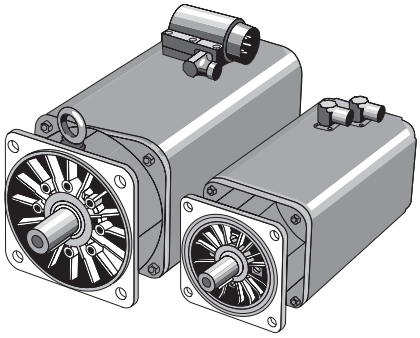
Servo Drive

Usually refers to an electronic device used to control the speed and *torque* of a *servo motor* as part of a closed-loop positioning control system.



Servo Motor

A *motor* designed with the dynamic response required for precision closed-loop positioning applications.



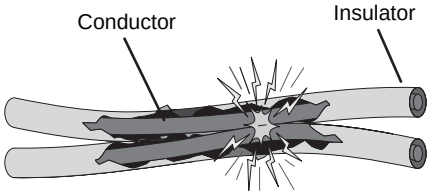
Servo Motors

Set Point

The value used by a control circuit as the desired value of a process variable.

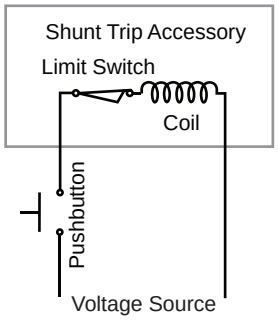
Short Circuit

A normally unintended low *resistance* path for *current*.



Shunt Trip

A circuit breaker accessory used to remotely trip a *circuit breaker*.



Single Quadrant Operation

Describes the operation of a *variable speed drive* that can provide *torque* to drive the motor, but cannot provide braking torque.

Slip

The difference between the *synchronous speed* of a three-phase induction motor and the *rotor* speed. Slip is often expressed as a percentage.

$$\% \ Slip = \frac{N_S - N_R}{N_S} \times 100$$

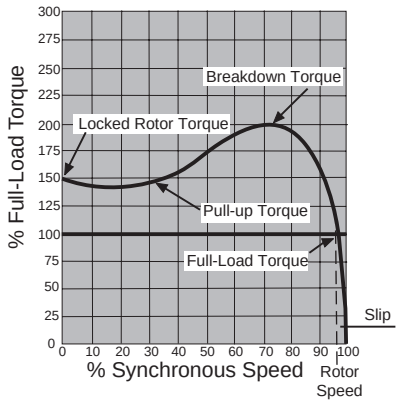
N_S = Synchronous Speed
N_R = Rotor Speed

Solid-State

Used to describe equipment that contains *semiconductor* devices in an electronic circuit.

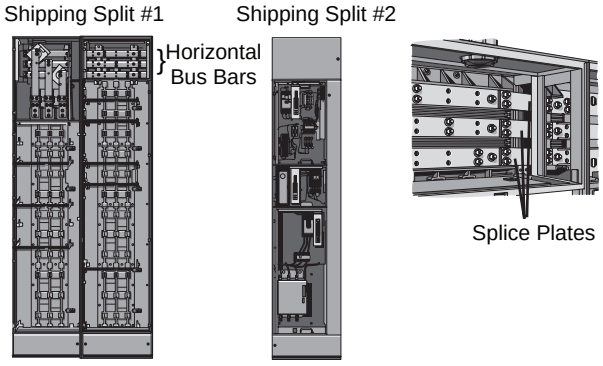
Speed-Torque Curve

A graphical representation of the *torque* provided by a motor over a range of speeds.



Splice Plates, Splice Bars

Plates or bars used to join the horizontal *bus bars* of adjoining *switchboard* or *motor control center* sections.



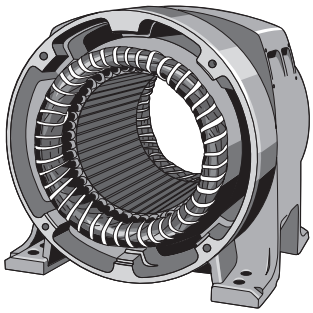
Starter Ratings

Motor Starters are rated according to size and type of load. *NEMA* and *IEC* rate *motor starters* differently. *IEC*-rated devices are rated according to maximum operational *current*. *NEMA* specifies sizes from size 00 to size 9.

NEMA Size	Continuous Amp Rating	HP @ 230 VAC	HP @ 460 VAC
00	9	1	2
0	18	3	5
1	27	7	10
2	45	15	25
3	90	30	50
4	135	50	100
5	270	100	200
6	540	200	400
7	810	300	600
8	1215	450	900
9	2250	800	1600

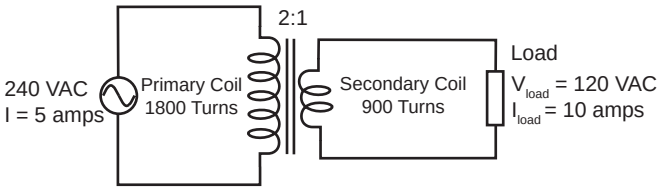
Stator

The stationary elements of the magnetic circuit of a rotating machine such as a motor.



Step-down Transformer

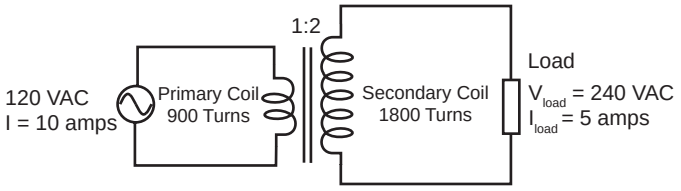
A *transformer* with more turns of wire in its primary coil than in its secondary coil. The step-down transformer is used to step down the primary *voltage* to a lower secondary voltage.



$$\frac{\text{Primary Turns}}{\text{Secondary Turns}} = \frac{\text{Primary Voltage}}{\text{Secondary Voltage}} = \frac{\text{Secondary Current}}{\text{Primary Current}}$$

Step-up Transformer

A *transformer* with fewer turns of wire in its primary coil than in its secondary coil. The step-up transformer is used to step up the primary *voltage* to a higher secondary voltage.



$$\frac{\text{Primary Turns}}{\text{Secondary Turns}} = \frac{\text{Primary Voltage}}{\text{Secondary Voltage}} = \frac{\text{Secondary Current}}{\text{Primary Current}}$$

Surge

An increase of at least ten percent in *current* and *voltage* that typically lasts only a few microseconds.

Surge Protection Device (SPD)

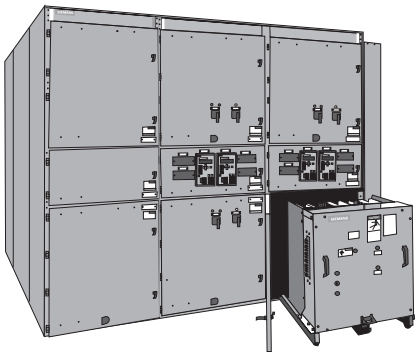
A device designed to provide a degree of protection for electrical equipment from the damaging effects of a *surge*.

Switchboard

A large panel or assembly of panels containing switches, *overcurrent* protective devices, buses, and associated instruments. Unlike panelboards, switchboards sometimes must be mounted away from a wall to allow access to rear-mounted equipment.

Switchgear

A coordinated design consisting of switching and interrupting devices and associated equipment such as control and protective devices and metering.



Synchronous Speed

The speed of the rotating magnetic field in a three-phase motor. Synchronous speed is determined by the line *frequency* and the number of motor poles.

$$\text{Synchronous Speed (Ns)} = \frac{120f}{P}$$

f = frequency
P = number of poles

Thermal-Magnetic

Used to describe a device that uses both heat and magnetism as part of its operating principles. For example, a thermal-magnetic *circuit breaker* can be tripped either by heat or magnetic force resulting from an *overcurrent*.

Thermistor

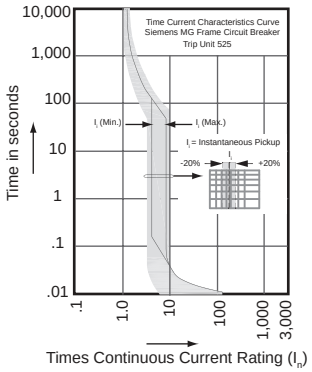
A device used to sense temperature that varies in *resistance* as temperature changes.

Thyristor

A family of multi-layer *semiconductor* switching devices that includes silicon controlled rectifiers (SCRs), gate turnoff (GTO) thyristors, triacs, and other similar devices. Thyristors are often used in *rectifier* or *power* switching circuits.

Time-Current Curve

A graph showing how long before a *circuit breaker* will trip at each level of fault *current*.

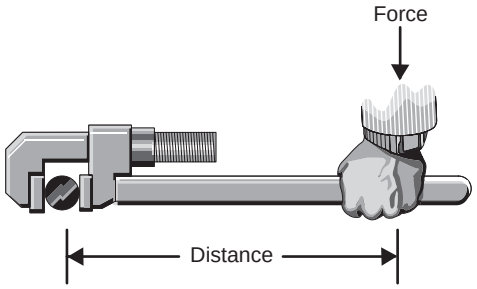


Timing Relay

A control relay that incorporates a preset delay in contact response. Some timing relays begin the time delay when the relay is energized. Others begin the time delay when the relay is de-energized.

Torque

A turning or twisting force. Since torque is expressed as a force times the length of the radius at which the force is measured, torque is represented in compound units such as pound-feet (lb.-ft.)



Totally Enclosed Fan Cooled (TEFC)

A motor *enclosure* type that restricts the flow of air into or out of the motor, but uses a fan to blow air over the motor's exterior.

Totally Enclosed Non-ventilated (TENV)

A motor *enclosure* type that restricts the flow of air into or out of the motor. Because there are no ventilating openings, all heat generated by the motor must be dissipated by conduction through the enclosure.

Transformer

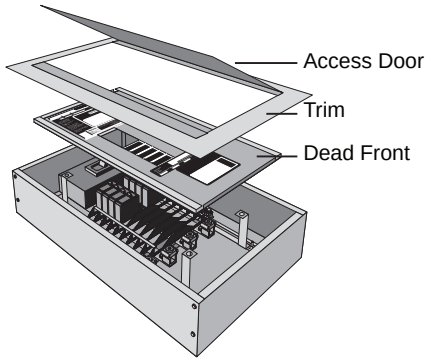
Coils of wire wound on a common frame that allow electrical energy to be transferred from one circuit to another. Transformers used in low frequency applications are commonly wound around an iron core to improve energy transfer.

Transistor

A *semiconductor* device which usually has three terminals although the names of the terminals are different for different types of transistors. Some types of transistors are used as electronic switches.

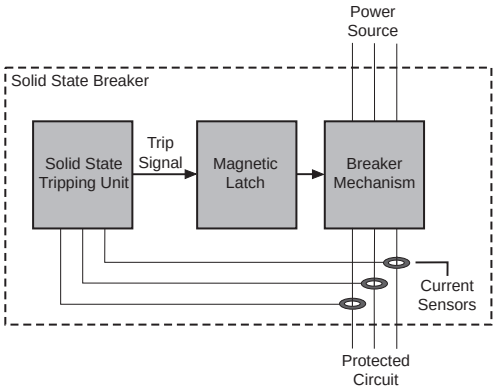
Trim

The front cover of a panelboard which includes an access door.



Trip Unit

The part of the *circuit breaker* that determines when the breaker will trip. Many circuit breakers use a *thermal-magnetic* or magnetic-only trip unit. Other circuit breakers have a *solid-state* trip unit with multiple adjustments to custom fit the circuit breaker's time current curve to the application.

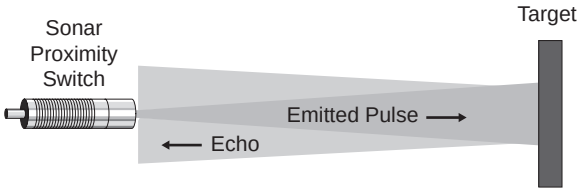


True Power

Also called real *power,* true power is the power dissipated by circuit *resistance*. True power is equal to I^2R and is measured in *watts*. True power is also equal to the *apparent power* multiplied by the *power factor*.

Sonar Proximity Switch

A type of *sensing switch* that uses high *frequency* sound to detect the presence of an object without coming into contact with the object. Sometimes referred to an an ultrasonic proximity switch.



Underwriters Laboratories (UL)

An independent product safety certification organization, Underwriters Laboratories, Inc. develops standards and tests products for safety. Products that pass UL tests can carry a UL mark. UL has several categories of marks based upon the type of product tested.

Var

The basic unit for *reactive power*. Shortened from volt-ampere reactive.

Variable Frequency Drive (VFD)

An electronic device used to control the speed a of an *AC motor*. A VFD controls the motor speed by varying the frequency and voltage applied to the motor. Also called an *AC drive*.

Variable Speed Drive

An electronic drive device used to control the speed of an electric motor. This term applies to both *AC Drives* and *DC Drives*.

Vector Control

A technique employed by some *variable frequency drives* that involves calculations of *AC motor* current vectors and precise control of motor flux to provide excellent speed and *torque* control.

Volt

The basic unit of *voltage*. The symbol for volt is "V."

Voltage

Also called difference of potential, *electromotive force*, or EMF. Voltage is a force that, when applied to a *conductor,* causes *current* to flow. Voltage is symbolized by "E" or "V" and is measured in *volts*.

Voltmeter

A meter designed to measure *voltage*.

Volts per Hertz (V/Hz) Operation

Describes the operation of many *variable frequency drives* that control the speed of an AC motor by varying the *frequency* of the *voltage* applied to the motor while maintaining a constant voltage to frequency ratio.

Watt

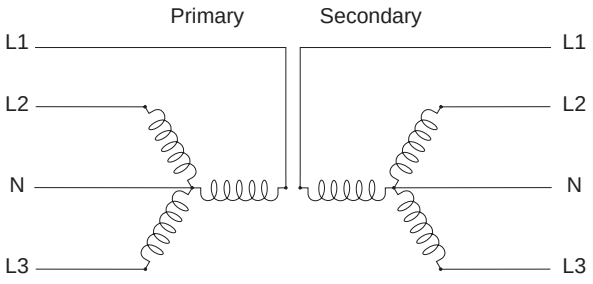
The basic unit of electric *power*. The symbol for watt is "W."

Word

Usually one or more *bytes* used to represent instructions or data in *digital* equipment.

Wye

A connection arrangement used for the primary and/or secondary of a three-phase *transformer*.



Wye-Wye (Y-Y)Transformer Configuration

Review Answers

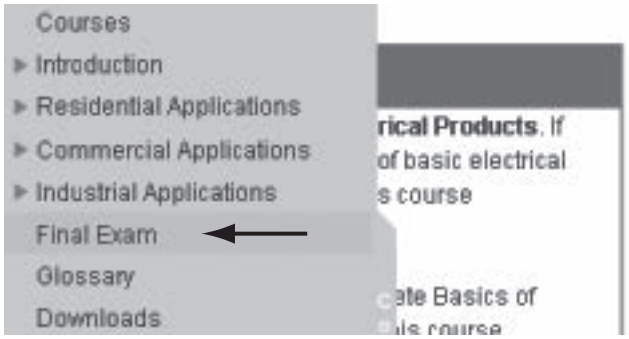
Review 1	1) Meter mains; 2) Uni-Pak meter centers, Power Mod with QuickSystem modular metering; 3) 100, 225; 4) combination; 5) SPD.
Review 2	1) 400; 2) 1200; 3) 2000; 4) IPS; 5) VL; 6) WL; 7). general, heavy, double throw.
Review 3	1) GM-SG; 2) four; 3) secondary unit substation; 4) Feeder, Plug-in; 5) SENTRON.
Review 4	1) b; 2) SIRIUS; 3) SITOP; 4) SINUMERIK.
Review 5	1) tiastar; 2) SIMOCODE pro; 3) 3RW30, 3RW40, 3RW44; 4) G110; 5) SIMOTION; 6) SIMATIC.
Review 6	1) Closed-loop; 2) SITRANS P; 3) SIMATIC WinCC; 4) SIMATIC PCS 7.

Final Exam Instructions

Before taking the final exam, it is recommended that you delete the temporary internet files from your computer's web browser. For most versions of **Internet Explorer**, you can do this by selecting **Internet Options** from the **Tools** menu and then clicking on the **Delete Files** button. If you do not perform this step, you may see a score of 0% after you submit your exam for grading.

The final exam for this course is available online at **http://www.usa.siemens.com/step**. This web page provides links to all our quickSTEP online courses. To complete the final exam for this course, click on the **Basics of Electrical Products** link.

Next, move your mouse over to the left so that the navigation bar pops out and select the **Final Exam** link. The final exam page will appear.



After you complete the final exam, click on the **Grade the Exam** button at the bottom of the page. Your score on the exam will be displayed along with the questions that you missed.

If you score 70% or better on the exam, you will be given two options for displaying and printing a certificate of completion. The **Print Certificate** option allows you to display and print the certificate without saving your score in our database and the **Save Score** option allows you to save your score and display and print your certificate. **The Save Score option is primarily intended for use by our distributors and Siemens employees.**